OCEANS FROM SPACE

TOWARDS THE MANAGEMENT OF OUR COASTAL ZONE

Frank E. Bunn
with
U. Domb, D. Huntley
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The Institute for Research on Public Policy / L'Institut de recherches politiques

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FOREWORD

The new Canadian coastal zone, which was extended from 12 to 200 nautical miles in January of 1977, has been under Canada's partial economic jurisdiction with respect to fisheries for over six years.

On 10 December 1982, together with 118 other countries, Canada signed the United Nations Convention on the Law of the Sea in Montego Bay, Jamaica, culminating a nine-year marathon of difficult and controversial negotiations. The Honourable Pierre de Bané, who co-signed the agreement for Canada, called the Convention "the greatest lawmaking achievement in the 37-year history of the United Nations."

In addition to confirming the 12-nautical-mile territorial sea, the Convention established Canadian sovereignty over the 200-nautical-mile economic zone along our coasts. This is clearly of special interest to a country with the longest coastline in the world. By January 1983, Canada extended its customs jurisdiction over activities related to exploitation of the continental shelf in this newly defined area.

Canada stands to benefit greatly from the full recognition of its offshore economic zone. However, reaping the benefits of the ocean resources, as well as of the activities performed in this zone, will require careful management. As operations expand in the 1980s and beyond, the success of our management will increasingly depend on our ability to monitor all the phenomena and activities in what the authors call Canada's "Resource Ribbon."

This timely study argues that remote sensing from space is the

only effective means by which Canada can develop control over the zone. The report explores new possibilities offered by advances in oceanic remote sensing technology to meet Canadian needs. It reviews Canadian strengths and weaknesses, and analyses options available to Canada. The report stresses the need to upgrade the "final link"–data management–to respond adequately to the "Resource Ribbon" challenge.

It is hoped that this report, which forms a part of the Technology and Society Program of the Institute, will help to contribute towards a solution to an emerging public policy problem.

Gordon Robertson
President
January 1983

AVANT-PROPOS

La zone côtière canadienne qui, en janvier 1977, passait de 12 à 200 milles nautiques, relève partiellement, depuis plus de six ans, de la compétence économique du Canada en matière de pêches.

Le 10 décembre 1982, le Canada signait, avec 118 autres pays à Montego en Jamaique, la Convention des Nations Unies sur le droit de la mer, qui mettait un terme à un marathon de neuf ans de négociations ardues et controversées. L'honorable Pierre de Bané, cosignataire de l'accord au nom du Canada, a qualifié la Convention de " la plus grande réalisation législative au cours des 37 ans d'existence des Nations Unies ".

En plus de confirmer les eaux territoriales de 12 milles nautiques, la Convention reconnaît la souveraineté du Canada dans une zone de 200 milles nautiques le long de nos côtes. Cela est évidemment d'un grand intérêt pour le pays ayant la plus grande côte au monde. En janvier 1983, le Canada avait commencé à exercer ses droits en matière de douanes en rapport avec les activités découlant de l'exploitation du plateau continental dans cette nouvelle zone.

Le Canada risque de profiter beaucoup de la pleine reconnaissance de cette zone économique au large des côtes. Il reste toutefois qu'il faudra gérer avec prudence si l'on espère récolter les bénéfices des ressources océaniques de cette région ainsi que des activités qui s'y dérouleront. À mesure que ces activités prendront de l'ampleur au cours des années 1980 et au-delà, le succès de notre gestion dépendra de plus en plus de notre aptitude à contrôler tous les phénomènes et

toutes les activités qui surviendront dans cette " ceinture de ressources ".

Cette étude pertinente soutient que la télédétection à partir de l'espace offre le seul moyen efficace au Canada pour la surveillance de cette zone. On y examine les nouvelles possibilités qu'offrent les progrès des techniques de télédétection des océans en regard des besoins du Canada. On y recense les forces et les faiblesses du Canada ainsi que les options auxquelles il fait face. Le rapport insiste sur le besoin de renforcer le " dernier maillon " – la gestion des données – afin de pouvoir réagir comme il se doit au défi posé par cette " ceinture de ressources ".

Il est à espérer que ce rapport, publié dans le cadre du programme d'études technologiques et sociales de l'Institut, aidera à la solution d'un problème de politique de plus en plus d'actualité.

Gordon Robertson
Président
Janvier 1983

NOTE

This report is one of a series of studies conducted as part of the Institute's Technology and Society Program, directed by Zavis Zeman, and was funded by the Government of Canada, Department of Fisheries and Oceans. Howard Edel of Fisheries and Oceans functioned as the scientific authority for the report.

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EXECUTIVE SUMMARY

The Oceans From Space report attempts, in four chapters, to demonstrate that satellite remote sensing technology could be used to comprehensively manage Canadian coastal zones.

The report opens by acknowledging that the importance of Canada's immense coastal resource base is generally well recognized and undisputed. Reaping the benefit of these resources, it is stressed, will require careful management, and the success of resource management will depend increasingly on our ability to obtain complete and accurate information. Without such information it will become increasingly difficult to ensure that Canada's offshore resources are managed to the benefit of all Canadians.

Unlike oceans research, which involves short-term data collection in small areas, the control of oceans operations requires routine monitoring and assessment of both the natural environment and human maritime activity over large areas. In situ measurements by buoys and instruments on ships have long been the principal source of information on the hydrography of coastal zones. But, if observations are to be made over larger areas, these measurement techniques have to be complemented. Airborne, low-altitude observation and data collection have proved very useful for some purposes. However, aircraft are restricted in range and by adverse weather conditions, and are expensive to use. In short there are significant deficiencies in present ocean data collection methods.

Remote sensing from space is the only effective means by which

Canada can expand and augment its present activities in monitoring and assessing oceans operations. The superiority of satellite imagery lies in the frequency of coverage, its regularity and uniformity, and in its relative low cost.

Despite its benefits, remote sensing can provide only a two-dimensional representation of three dimensional spaces. Thus, in situ sensors are needed as well to provide "ground truthing," that is, to complement and verify information gathered by remote sensors.

A great number of parameters can be measured over large areas by in situ acoustic remote sensing systems that are presently operated by the military. However, data produced by the military systems are often discarded, although they could be advantageously applied to civilian needs if they were affordable.

Even when coupled with in situ systems, existing spaceborne remote sensing systems are not without deficiencies. One satellite does not have the full complement of sensors, and another is designed for research but not for operational purposes. A third satellite collects data for American purposes, and these data are not always accessible.

At present, the greatest obstacle to the exploitation of the rich data that are collected is the lack of complete data management systems. The time to forge this final link is now.

In Chapter Two, an attempt is made to identify potential products of satellite remote sensing. The nature of Canada's geography entails some specific requirements: that is, total coverage, all-weather systems, night sensing, and high-resolution imagery. Some of the proposed uses of satellite remote sensing could be operational quite quickly, while others will require significant technological development.

Commercial transport ships, exploration and supply ships, and offshore platforms need accurate information on weather conditions, sea conditions, ocean currents, ice mapping and iceberg movement. Superior forecasting would allow for better ship routing, greater safety, and improved fuel economy, together with lower insurance costs and higher load factors, which would yield higher profits. Search and rescue missions conducted by the Coast Guard could also be made more effective.

The potential of satellite remote sensing for improving weather

observation is great and has already been realized in many cases. The chief advantage of these systems for weather observation is the broad and uniform spatial coverage provided by the satellites, and their regular and reliable monitoring. Satellites can be used to measure sea surface winds, to help refine sea surface pressure maps, to map wave heights, and to chart the dominant direction and length of waves (through new techniques using radar sensors). Forecasts of upper ocean currents using satellite images of sea surface temperature are now also feasible.

The demand for accurate sea ice information will increase as arctic and sub-arctic regions are developed. Sea ice monitoring has been identified by the Canadian SURSAT program as the main requirement in those regions. Sea ice mapping from space could well become operational in this decade. The passive microwave and synthetic aperture radar sensors from the SEASAT and NIMBUS-6 programs are promising as well.

Satellite imagery can be used to map Canada's long ocean coastline, which is remote, ice covered, and subject to severe climatic conditions. Standard survey and mapping techniques are time consuming and expensive, with the result that coastline mapping is often inaccurate. If hydrographic maps of coastal waters are to be accurate, they cannot be produced without satellite imagery. Changes in the coastline, whether due to erosion or human activity, could then be monitored. However, oil spills cannot yet be detected or tracked remotely.

Remote sensing can also be useful to fisheries in the following three ways: (1) by improving the safety of fishing activity; (2) by monitoring the movement of domestic and international fishing fleets; and (3) by providing information to help in the effective management and assessment of fish stocks and fish husbanding. Chlorophyll, which is indicative of food sources, can be mapped by remote sensing, and can aid in predicting the presence of fish schools.

Yet another application of surveillance by satellite is that of a deterrent to violators of Canadian coastal waters. Satellite imagery can substantially complement the patrolling efforts of Canadian ships and aircraft, such that all areas of surveillance—fishing vessels, off-

shore exploitation, shipping and defence—would benefit.

Finally, recent anomalies in seasonal climate have raised the need for a better understanding of climate. Measurement of critical climate parameters for studies attempting to provide estimates of long-term changes in the earth's climate will require a careful integration of satellite remote sensing techniques with existing in situ measurement programs.

In the third chapter, the present level of remote sensing expertise in Canada is discussed. The Canada Centre for Remote Sensing (CCRS) is the national leading agency, and is guided by the Inter-Agency Committee on Remote Sensing. Some provincial governments have their own research centres, and many universities, as well as twenty to thirty commercial firms, are also active in the field. In the area of oceanic studies, the leading agencies are the Bedford Institute of Oceanography in the east and the Institute of Ocean Sciences in the west. In this report, most of the Canadian groups interested or active in the field are listed.

It should be understood that Canadian efforts are not being conducted in a vacuum. The United States has made the most significant efforts in terms of funds invested and results obtained, and is unquestionably the world leader in oceanographic remote sensing. The Soviet Union also has its own programs, as do Japan and the members of the European Economic Community.

If Canada is to obtain remote sensing data to manage its oceans and coastlines, it must choose one of the following options. The first option is to make the maximum use of the information provided by existing satellites and airborne systems of our own, and by those of other countries.

Canada's second option is to participate in the satellite programs of other nations by sharing costs, expertise, data and results. Canada could piggyback oceanic sensor systems on the space platform systems that are being prepared for launch over the next one to five years by the United States, France, Japan and the members of the European Economic Community.

However, if we are really serious about mastering our coastal zone, Canada may have, in fact, only one option, a third option—that of

building its own all-Canadian satellite, with its own sensor systems and data production facilities. It is obvious that we should not discontinue the current effort to piggyback on other programs and extract all available information from existing systems.

Chapter Four elaborates on the conclusions of the first chapter regarding the critical importance of information products. Regardless of which of the three alternative courses of action is finally selected, a dramatic improvement in oceanic remote sensing will be achieved by upgrading data management to produce information useful to the final user.

To this end, Canada should establish a facility with a mandate to manage oceanic data. Its primary goal should be the creation, development, and dissemination of information products for those involved in oceans operations. The facility should complement the work of existing establishments, and should involve all interested parties in its management. The first priority of the facility should be a program to inform users of the availability of information products.

Of several possible configurations of the oceanic data system, the proposed central facility—to be called the Marine, Academic, Government and Industry Centre (MAGIC)—is the least expensive. The capital costs for such a centre are estimated to be approximately seven million dollars, with a yearly operational budget in the order of four million dollars (1982). The core funding could be obtained from the National Sciences and Engineering Council of Canada. If the facility is based in the province of Ontario, the provincial BILD Program could be approached for support. Once users find the service useful, they should start to pay for the information, eventually making the service self-sufficient.

In this chapter, the objectives of the Oceans Information System (OIS), to be housed in MAGIC, are also formulated; OIS would consist of a network of agents who would demonstrate to users the various applications of oceanic remote sensing. In addition, OIS would offer Canadians the opportunity to develop expertise in complex data systems, which could boost our electronics industry. The export potential of oceanic remote sensing products is also stressed in the final chapter.

The report concludes with several technical recommendations. The thrust of these recommendations is that, if Canada mobilizes its potential well, it can become the world leader in ocean and coastal zone management.

ABRÉGÉ

Le rapport **Oceans From Space** tente, dans ses quatre chapitres, de démontrer qu'il serait possible d'utiliser les techniques de télédétection pour gérer globalement les régions côtières du Canada.

Le rapport reconnaît tout d'abord que personne ne conteste l'importance des immenses ressources côtières du Canada. On insiste sur le fait que, pour tirer profit de ces ressources, il faudra les gérer prudemment; le succès de cette gestion dépendra de plus en plus de notre capacité d'obtenir des renseignements complets et précis. Sans de tels renseignements, il sera de moins en moins facile de s'assurer que les ressources au large des côtes sont gérées au profit de l'ensemble des Canadiens.

À la différence de la recherche sur les océans, qui comporte une collecte de données à court terme dans des régions restreintes, la surveillance des opérations océaniques exige une évaluation et un contrôle courants à la fois du milieu naturel et de l'activité humaine maritime sur de vastes étendues. Des mesures in situ au moyen de bouées et d'instruments sur des navires sont depuis longtemps la source principale de renseignements sur l'hydrographie des régions côtières. Toutefois, il nous faut, si l'on espère réaliser des observations sur de vastes superficies, compléter ces techniques de mesure. Les observations et la collecte de données à basse altitude réalisées au moyen d'avions se sont avérées fort utiles à certaines fins. Toutefois, les avions sont limités dans leur portée, sont affectés par les conditions du temps et coûtent cher. Bref, les méthodes actuelles de collecte de

données sur l'océan sont déficientes.

La télédétection à partir de l'espace représente le seul moyen efficace qui s'offre au Canada pour accroître et augmenter ses activités de contrôle et d'évaluation des opérations océaniques. Les images par satellite sont supérieures de par leur quantité, leur régularité et leur uniformité ainsi que de par leur coût relativement peu élevé.

Malgré ces avantages, la télédétection n'offre qu'une représentation à deux dimensions d'espaces à trois dimensions. Il faut donc avoir recours à des capteurs in situ pour obtenir une vérification au sol, c'est-à-dire pour compléter et vérifier des renseignements amassés par les télédétecteurs.

On peut mesurer un grand nombre de paramètres sur de vastes étendues grâce à des systèmes de télédétection acoustique in situ qui relèvent actuellement des militaires. Toutefois, les données procurées par les systèmes militaires sont souvent mises au rebut, et ce malgré le fait qu'elles pourraient servir à des besoins civils si on pouvait se les payer.

Les systèmes actuels de télédétection par satellite ne sont pas sans défauts, même lorsque combinés à des systèmes in situ. Un des satellites ne dispose pas d'un ensemble complet de capteurs, tandis qu'un autre est conçu pour la recherche mais non à des fins opérationnelles. Le troisième satellite collecte des données pour les Américains, données qui ne sont pas toujours disponibles.

À l'heure actuelle, le manque de systèmes globaux de gestion des données constitue le principal obstacle à l'exploitation de la grande quantité de données collectées. Le temps est venu de surmonter cet obstacle.

Au chapitre 2, on tente d'identifier les produits éventuels de la télédétection. La nature de la géographie canadienne nous dicte certaines contraintes : c'est-à-dire, une couverture complète, des systèmes pour tous les temps, la détection de nuit et des images à grande définition. Certaines des utilisations proposées de la télédétection pourraient devenir opérationnelles assez rapidement, tandis que d'autres exigeront passablement de développement technologique.

Les navires de transport commerciaux, les navires d'exploration et

de ravitaillement, et les plates-formes au large des côtes ont besoin de renseignements précis sur les conditions du temps, les conditions de la mer, les courants ainsi que les mouvements des glaces et des icebergs. De meilleures prévisions permettraient un meilleur acheminement des bateaux, une plus grande sécurité et une amélioration des économies de carburant ainsi qu'une baisse des frais d'assurance et une augmentation des capacités de charge qui procureraient des profits plus élevés. Les missions de recherche et de sauvetage effectuées par la garde côtière deviendraient aussi plus efficaces.

La télédétection offre de grandes possibilités dans le domaine de la prévision météorologique, dont certaines ont déjà été concrétisées. Ces systèmes ont surtout l'avantage d'offrir une couverture vaste et uniforme grâce au satellite ainsi qu'une surveillance régulière et fiable. On peut utiliser les satellites pour mesurer les vents à la surface des océans, pour aider à préciser les cartes de la pression à la surface des océans ainsi que pour établir des cartes de la hauteur des vagues, et des cartes de la direction dominante et de la longueur des vagues (grâce à des nouvelles techniques utilisant des détecteurs radar). On peut aussi maintenant établir des prévisions des courants de surface des océans à l'aide d'images satellite de la température de la surface de l'océan.

À mesure que se développeront les régions de l'Arctique et du Grand Nord, les demandes de renseignements précis sur les glaces augmenteront. On a déterminé, dans le cadre du programme canadien SURSAT, que le contrôle des glaces constituait le principal besoin dans ces régions. La cartographie des glaces océaniques à partir de l'espace pourrait bien être réalisable d'ici la fin des années 1980. Les détecteurs micro-onde passifs et les détecteurs radar à ouverture synthétique des programmes SEASAT et NIMBUS-6 sont également prometteurs.

On peut utiliser les images par satellite pour dresser des cartes de la côte canadienne qui est très longue, éloignée, couverte de glace et sujette à des conditions climatiques très rigoureuses. Les techniques de cartographie et de relevés classiques sont très onéreuses en temps et en argent : il s'ensuit que les cartes des côtes sont souvent imprécises. On ne peut produire des cartes hydrographiques précises des eaux côtières sans avoir recours aux images par satellite. On pourrait alors relever les changements de la côte occasionnés soit par l'érosion ou par

l'activité humaine. On ne peut toutefois encore déceler ou suivre les déversements de pétrole.

La télédétection peut aussi servir aux pêches de trois manières : 1) en améliorant la sécurité de la pêche; 2) en contrôlant le mouvement des flottes de pêche intérieures et internationales; et 3) en fournissant des renseignements pour aider à la gestion et à l'évaluation efficace des stocks de poissons et des élevages. On peut établir, grâce à la télédétection, des cartes du chlorophylle, qui est un indicateur de sources d'alimentation; cette technique peut aussi aider à prédire la présence de bancs de poissons.

La surveillance par satellite peut aussi aider à décourager ceux qui violeraient les eaux côtières canadiennes. Les images par satellite peuvent compléter le travail de patrouille des navires et des avions canadiens de telle sorte que tous les domaines de surveillance – les bateaux de pêche, l'exploitation au large des côtes, le transport maritime et la défense – en profiteraient.

En dernier lieu, les récents soubresauts du climat ont fait poindre le besoin d'une meilleure compréhension en cette matière. La mesure des paramètres critiques du climat aux fins des études destinées à fournir des prévisions de longue durée des changements du climat de la terre exigera une intégration bien pensée des techniques de télédétection par satellite et des programmes actuels de mesure in situ.

Le troisième chapitre traite du niveau actuel d'expérience en télédétection au Canada. Le Comité interministériel pour la télédétection oriente le travail du Centre canadien de télédétection (CCT), le principal organisme national. Certains gouvernements provinciaux ont leur propre centre de recherche, et de nombreuses universités de même que de vingt à trente entreprises commerciales participent également à ce travail. Dans le domaine des études de l'océan, les principaux organismes sont le Bedford Institute of Oceanography dans l'Est et l'Institute of Ocean Sciences dans l'Ouest. Ce rapport renferme la liste de la plupart des groupes canadiens qui s'intéressent à ce domaine ou qui y travaillent.

Il faut comprendre que le Canada ne fait pas cavalier seul. Ce sont les États-Unis qui ont consenti les plus grands efforts en termes d'argent et de résultats : ils sont sans conteste les chefs de file en

matière de télédétection océanographique. L'Union soviétique a aussi ses programmes, de même que les Japonais et les membres de la Communauté économique européenne.

Si le Canada désire disposer de données de télédétection pour gérer ses océans et ses côtes, il doit choisir une des solutions suivantes : il peut en premier lieu utiliser au maximum les renseignements fournis par ses propres avions et ses satellites ainsi que par ceux des autres pays.

En deuxième lieu, le Canada peut participer aux programmes de satellite des autres pays en partageant les frais, les connaissances, les données et les résultats. Le Canada pourrait raccorder des systèmes de détection océanique aux systèmes de plates-formes dans l'espace que les États-Unis, la France, le Japon et les membres de la Communauté économique européenne s'apprêtent à lancer d'ici cinq ans.

Toutefois, s'il tient réellement à garder la maîtrise de sa zone côtière, le Canada n'a en fait qu'un seul choix, la dernière des trois solutions : c'est-à-dire construire un satellite tout à fait canadien avec ses propres systèmes de détection et ses propres installations de production de données. Il est évident que nous ne devons pas mettre fin aux efforts en vue de s'inscrire dans d'autres programmes et de tirer tout le profit possible des systèmes actuels.

Au chapitre 4, on élabore sur les conclusions du premier chapitre au sujet de l'importance critique des produits d'information. Peu importe sur quelle solution le choix se portera, c'est en améliorant la gestion des données de manière à produire des renseignements réellement profitables à l'utilisateur que l'on réalisera des progrès sensibles dans la télédétection des océans.

À cette fin, le Canada devrait créer un centre de gestion des données océaniques. Ce centre devrait s'attacher avant tout à créer, à développer et à diffuser des produits d'information pour toutes les parties intéressées aux opérations océaniques. Cette installation devrait compléter le travail des installations actuelles; toutes les parties intéressées devraient participer à sa gestion. Sa première priorité devrait être la mise en oeuvre d'un programme destiné à informer les utilisateurs de la disponibilité des produits d'information.

Parmi les différentes configurations possibles du système de

données sur les océans, l'installation centrale proposée – qui s'appellera le Centre d'études maritimes du gouvernement et de l'industrie (CEMGI) – serait la moins chère. On évalue à environ sept millions de dollars les immobilisations nécessaires pour un tel centre et à quatre millions de dollars (1982) le budget d'exploitation annuel. Le Conseil de recherche en sciences naturelles et en génie du Canada pourrait fournir l'essentiel des fonds. Si le centre est situé en Ontario, on pourrait obtenir l'appui du programme provincial BILD. Une fois que les utilisateurs auront appris à connaître les bienfaits du service, ils devraient commencer à payer pour les renseignements, ce qui permettrait au service de devenir autosuffisant.

On établit aussi à ce chapitre les objectifs du Système d'information océanique (SIO) qui doit faire partie du CEMGI; le SIO comprendrait un réseau d'agents qui démontreraient aux utilisateurs les diverses applications de la télédétection des océans. De plus, le SIO offrirait aux Canadiens l'occasion de développer leur expérience en matière de systèmes de données complexes, ce qui profiterait à notre industrie de l'électronique. On insiste aussi, au dernier chapitre, sur les possibilités d'exportation des produits de télédétection des océans.

Le rapport se termine par plusieurs recommandations d'ordre technique. L'essentiel de ces recommandations veut que, si le Canada sait tirer parti de ses possibilités, il puisse devenir le chef de file mondial en matière de gestion des zones océaniques et des zones côtières.

Chapter One
THE NEED FOR QUALITY INFORMATION

Canada has the longest coastline of any country in the world. The coastal oceanic area bounded by the 200-mile limit is nearly half as large as Canada's entire land area. The supply of resources in this coastal zone, which surrounds Canada like a ribbon, is immense, and the quality and importance to Canada of this resource base are well recognized. The abundant fisheries, and resources such as oil, natural gas and seabed minerals, are potential sources of future wealth and power. The significance of the area in providing both transportation corridors for commercial shipping and national security buffer zones is also undisputed.

Coastal and Ocean Resource Management

Reaping the benefits of these bountiful ocean resources clearly requires careful management, not only in traditional coastal areas, but also in the vast, previously unexplored frontier zones. A central proposition of this report is that, as activity in these areas expands in the 1980s and later, the success of resource management will depend increasingly on our ability to obtain complete and accurate information about activities in the Resource Ribbon.

There is already a substantial amount of activity in this coastal area, and more is imminent. The management of fish stocks and of the national and international fishing fleets requires consistent, accurate observation. The growth in coastal oil and gas exploration has led to significant increases in shipping to service these activities,

and successful arctic exploration will introduce new tanker shipping. Rapid expansion of offshore oil, gas and mineral exploration must be accompanied by increased monitoring. In addition, the risk of environmental contamination will pose particular challenges in the management of coastal resources.

Increased surveillance and the need to maintain control over Canada's coastal resources will require, however, substantially greater efforts to gather the necessary information and to apply it to the management of ocean resources and industries. Without such efforts, it will become increasingly difficult to ensure that Canada's offshore resources are managed for the benefit of all Canadians. Moreover, as technological change pushes exploration and resource development further into formerly inaccessible regions, the problems of gathering the information necessary to manage coastal resources will become even more acute.

Oceans management is a continual process of monitoring both the ocean environment and man's activity in a zone for the purposes of understanding, charting, predicting and, where possible, controlling them. Our ability to adequately manage our coastal area will depend on our ability to collect and process the necessary information.

Another central proposition of this report is that remote sensing from space is the only effective means by which Canada can expand and augment present monitoring efforts, so as to explore, survey and patrol all of its economically important oceans and coastlines for purposes of oceans operations. Present efforts are adequate for the limited oceans management now being done. However, the expansion of exploration and development of our coastal ocean zones in the 1980s and 1990s demands major advancement of these efforts. Our approach emphasizes the need to complement and improve upon today's airborne and in situ remote sensing technology and existing satellite remote sensing.

Advantages of Oceanic Remote Sensing

In situ measurements have long been the principal source of information on the hydrography of coastal zones. Local spot measurements, such as temperature, salinity, turbidity, drift currents and water samples, are

made by instruments on ships and buoys. Such measurements are accurate and can monitor conditions in varying water depths. However, surveying a large area by making a series of spot measurements is time consuming and expensive. Additionally, this method of surveying will not work if the ocean phenomena being sensed change rapidly. To monitor this huge, complex and variable zone effectively by the spot measurement method alone would be practically impossible due to time, manpower and budgetary constraints.

The size of Canada's coastal zones requires that in situ techniques be supplemented by remote sensing, which would make it possible to observe much larger areas. However, it is generally the case that only surface conditions can be measured by this method. Airborne, low altitude observation and data collection are, thus, key components of remote sensing in coastal zones. Although they are limited primarily to monitoring ice and iceberg conditions and to surveying visible coastal areas, the development of more sophisticated radar and infrared techniques will undoubtedly result in greater use of aircraft in the future. Although a proper cost analysis must be done for each survey, some missions will be most cost effective if aircraft are used. However, aircraft are restricted in range and by weather conditions, and are expensive (and potentially dangerous) to operate. In addition, phenomena that warrant observation can occur during storms when aircraft are grounded (e.g., high waves, ice break-up, strong winds).

Remote sensing from satellite altitudes overcomes many of these limitations and is especially useful for obtaining the small-scale low-resolution operations data that have immense scientific and economic value in planning the development of coastal zones. The superiority of satellite imagery over that obtained by airborne or surface-level sensors lies in the frequency of coverage of satellite overflights; in the regularity and uniformity of coverage, unbiased by better measuring in the areas where population is located; in the relative low cost of each pass, as compared with the high cost of the average aircraft operation; and in the ability of satellites to maintain coverage of the entire 200-mile Resource Ribbon. The different types of remote monitoring, and the uses to which they can be put, are discussed in Chapter Two. It is, however, the combination of in situ, airborne and satellite data that

will provide the qualitatively new extension of our current ocean information capability.

The Inadequacy of Present Monitoring Efforts

To collect data on its coastal zones, Canada presently uses in situ, airborne and satellite sensing. However, there are significant deficiencies in collection methods and in the data thus assembled.

Remote sensing of oceans from space produces two-dimensional representations of what are essentially three-dimensional oceans and coastlines. That is, only surface conditions or conditions very near the surface are displayed. Therefore, the importance of using data gathered in situ to complement information from space cannot be over-emphasized. In situ sensors deployed from floating platforms (towed, anchored or buried) provide direct measurements of local conditions. Arrays of moored instruments also provide long-term series data for process-oriented studies. As well as providing information about conditions beneath the ocean surface, these systems provide data that are invaluable in verifying information obtained from remote sensors. This process is called "ground truthing."

Canada has substantial expertise in the development and use of these systems; Canadian developments in instrumentation and measurement techniques keep it in the forefront of oceans management technology. The Canadian Atmospheric Environment Service (AES), in co-operation with the federal Department of Fisheries and Oceans (on the east coast, the Bedford Institute of Oceanography in Nova Scotia, and on the west coast, the Institute of Ocean Sciences in British Columbia) operates an important, but small-budget, buoy, a ship and an airborne program for weather research, ice reconnaissance and oceanographic purposes. However, despite their usefulness in research and for ground truthing, in situ sensors can measure only isolated conditions, affording coverage that is too localized, and the data they produce may not be suitable for all applications in oceans management.

The information obtained directly by in situ measurement of surface parameters (wind velocity, atmospheric pressure, temperature, water content, etc.) and subsurface parameters (temperature, salinity, current velocities, suspended sediments, pollution concentration,

chlorophyll, etc.) could be augmented by in situ acoustic remote sensing systems. These systems can operate either in the passive, or listening only, mode or the active mode in which the echoes of sound beams sent by the sensor are recorded. Acoustic sensors can measure, with varying reliability, many factors related to the state of the ocean near the sensors. These factors may include heat content, wind stress, sea topography, currents, stratification, fish schooling patterns, pollution and sedimentation. Some of the passive systems, such as the extensive acoustical monitoring systems used today by the military, are capable of acoustic sensing over many hundreds of miles of coastline.

At present, Canada is linked directly with the United States' anti-submarine networks, CAESAR and SOSUS, which acoustically monitor millions of square miles of ocean. The data produced by these military systems could be applied to civilian needs in tracking icebergs, oil spills, fishing boats, floating platforms and, possibly, fish school migration. Further analysis of the information already gathered by military sensors could provide valuable data to complement sensor information, collected directly for civilian purposes.

Even where Canada has access to data such as those available from the SOSUS acoustic ocean sensing system, there is a serious impediment to information dissemination. Some of these data are collected off of the Canadian coasts and are transmitted to U.S. analysis centres. After some delay, portions are returned to the Canadian military. However, less than 10 per cent of the data collected is of interest to the Canadian and American military; the bulk of the information relates to surface ships, and is largely discarded. The Canadian military can pass this information on to other government agencies, but would do so at a prohibitive cost, calculated at approximately 90 per cent of all operational and capital expenses for Canadian SOSUS facilities.[1] Thus, much of the information from these acoustic sensors, which has the potential for application to a range of coastal activities, is unexploited.

Present spaceborne remote sensing systems also suffer from serious deficiencies. Polar-orbiting satellites are required for Canadian operations, but at present, those that collect relevant data are unsatisfactory from several points of view. For example, the American

NOAA-6 is primarily a meteorological satellite and does not have the full complement of sensors required. Another satellite, the NIMBUS-7, which is an experimental meteorological satellite, does have the appropriate sensors, but transmits its high-quality data to U.S. ground stations, not to Canadian receivers.

Canada, thus, must rely on information collected by another country for its own purposes. Moreover, gaining access to this information is a major challenge. Since the NIMBUS-7 was designed for research rather than operational purposes, the data it collects must be processed if it is to be disseminated in a usable form. This process usually has low priority and, when data can be obtained at all, only small amounts of information covering short time periods are available. Then, the data are usually more than a year old; users outside of the country that owns the satellite system are low on the priority list for data delivery.

The most serious impediment to the effective conduct of the necessary oceans research and operations is the absence of adequate data management facilities for the collection, storage and retrieval of data, for data base management and, most important, for the development and dissemination of information products derived from these data.[2]

Finally, several technical problems exist with the oceans management technology that is currently implemented. First, only limited airborne tactical data are collected, and these are localized mainly to east and west coast population centres. Secondly, although excellent data are gathered from in situ buoys, these buoys are usually few, and are sparsely deployed. Both of these technical problems result in an insufficient amount of the relevant data being gathered. Thirdly, ship-collected data are often of poor quality if gathered by regular transport vessels (although oil rigs and military "ships of opportunity" do collect good-quality data). However, when gathered by research vessels, the amount of data, although of high quality, is limited by the small amount of annual sea time that is permitted, due to cost restraints. And fourthly, apart from weather satellite data, very limited satellite data are being made available. This is severely hampering the research needed to assess satellite remote sensing by the

users, particularly in the Canadian context.

Time to Forge the Final Link

Canada is conducting serious efforts in oceans research and oceans operations. Research efforts are focused at the Bedford Institute of Oceanography and at the Institute of Ocean Sciences. Operations efforts are organized under the direction of the Atmospheric Environment Service, with the Ice Information Centre handling aircraft, satellite and some boat data, and under the direction of the Canadian Forces Meteorological and Oceanographic Centre, which handles ship data (research ships and ships of opportunity), drilling rigs and buoy data, and vessels and aircraft information from the Department of National Defence. Some valuable data are also available from geological explorations, in situ buoys, airborne visual ice reconnaissance, and other sources. As stated previously, not enough relevant data can be gathered, due to technical difficulties with the current systems. However, because of the absence of facilities to store them, much of the data that are actually collected must be discarded.

The Canadian government has long recognized the importance of the Resource Ribbon, and it appears that there is a new sense of urgency for action. In his statement to the House of Commons on 9 April 1981, John Roberts, then Minister of State for Science and Technology, called for advanced systems dedicated to gathering information on coastal zones. The Canadian Space Program Plan for 1981/82 to 1983/84 allots some $64 million in additional expenditures for this purpose, with some $40 million committed to remote sensing. Funds are committed for ground stations ($14 million), weather research ($3 million), sensors ($1 million), and industrial technology development ($20 million). However, since oceanic remote sensing has been seen primarily as a research, rather than an operational, activity, no major funds have been made available for data management.

As we move towards the operational use of oceanic remote sensing, and with new data flowing in even larger volumes, the present system of processing the data will result in a critical bottleneck. The government of Canada's expenditures will, therefore, contain a serious omission if no major funds are made available in this area.

If Canada is to utilize all useful information afforded by remote sensing technology, attention has to be refocused on the critical final element—the link between data and users. While this refocusing should not impose any limitations on current oceans research, priority now has to be placed on upgrading Canadian data management and data facilities to respond adequately to the Resource Ribbon challenge.

Notes

1. The calculation of SOSUS data costs is based on the premise that, as only 10 per cent of SOSUS data are required by the military, someone else should pay the other 90 per cent of the system if they wish to use the data it produces.
2. We have intentionally not differentiated between raw data (instrumented output), analysed data (human and/or computer-interpreted), and data products (information produced routinely for the user).

Chapter Two
OCEANIC REMOTE SENSING APPLICATIONS: CANADIAN NEEDS AND NEW POSSIBILITIES

The objective of this chapter is to identify the potential products of remote sensing that an upgraded data management system could provide to its users. Most of the products discussed in this section are of universal importance, and are being developed concurrently by many other countries.

As mentioned previously, Canada's particular situation will require not only the development of general expertise, but also of special techniques to meet the needs of Canadians. For example, Canada's geography requires satellite orbits that can encompass the whole country—a vast area, particularly with the northern regions. Many earlier systems, and some of those now being proposed, do not satisfy this requirement. Cloud cover, fog, and storms, which characterize much of Canada's coastal zones—particularly the east coast—mean that Canadians must emphasize the development of all-weather systems, rather than of visible and infrared techniques. In addition, much of the area to be surveyed is in darkness for a good part of the year, further limiting the application of visible techniques.

Another characteristic of Canadian coastlines is ice cover. Hence, precise mapping of icebound coastlines is particularly important for Canada, especially as we become increasingly active in arctic navigation. Finally, many of the areas over which Canada wishes to maintain sovereignty are very remote and extremely difficult to access.

In this chapter we discuss the full range of required Canadian data products. Once sufficient data are available, some products could

become operational very quickly because they are easily defined and the accuracy of the imagery has already been proven. Examples of such products are data on sea surface winds and waves.

At the other end of the spectrum are products that will require substantial research and development before they become useful. For example, Synthetic Aperture Radar (SAR) requires significant technological development before it can be used for routine surveillance. Similarly, substantial research into the uses of chlorophyll detection in fisheries management is necessary.

Between these two extremes there exists a range of potential products that will require a combination of research and operational development, as well as the education of its users, before they can be routinely useful.

The following discussion of remote sensing data products is divided into five sections, each corresponding to a specific use:

- Shipping, Transportation and Offshore Development
- Coastal Mapping and Environment Change
- Fisheries
- Surveillance
- Climate Studies

Shipping, Transportation and Offshore Development

Ocean vessels operate in a hostile environment. Commercial transport ships, exploration and supply ships, and floating exploration platforms need the best available information on weather conditions, on sea conditions, on ocean currents and, most importantly for northern operations, on ice mapping and iceberg movement. Improved information on winds, waves and currents could produce superior forecasting ability and would allow the shipping industry to schedule better ship routing. Safety would be improved by avoiding bad weather and rough seas, and fuel-efficient routes could be identified.

Improving safety and minimizing risks to ships and their cargoes would in turn permit lower insurance costs. In many cases the improved information would allow greater loads to be carried and, thus, greater profits to be realized. Accurate, up-to-date wind and wave information is vital for ocean-going vessels travelling near coastlines, and for those

off-loading or "load lightening" (transferring some cargo) to smaller inland fleet ships. This information would allow load lightening to be carried out much closer to land, thereby saving time and operating costs for the landing vessels as well as providing more sheltered safety for the ocean vessels. Coast guard operations would also benefit from the improved safety that more accurate and reliable weather reports would offer.

Oceanic remote sensing could also be very useful for search and rescue operations, as the international Search and Rescue Satellite-Aided Tracking (SARSAT) project has already proved. The satellite was able to relay distress messages instantly and pin-point the location to within one kilometre of accuracy, thus allowing for fast, targeted deployment of rescue teams.

Eventually, search and rescue operations could use remote sensing imagery as well, such as that from the high-quality SAR, to locate and track larger ships. However, this application has not been fully proved and will not be available on an operational basis until significantly more research and development has been carried out. If this imagery is to be of value, it must be produced on a daily basis and cover a sufficient area. It will be essential to obtain it in a usable format and within a few hours of the original satellite observations. The establishment of an infrastructure to interpret, package and disseminate this information will thus be a critical requirement.

Three major areas of concern for shipping and offshore development are weather observation, wave conditions and sea ice mapping. They are discussed in detail below.

Weather Observation

The potential of remote sensing for weather observation has already been realized. For example, the GOES weather satellites and rain-monitoring radars are used routinely for this purpose. The chief advantage of satellites for remote sensing observation is their broad and uniform spatial coverage and their regular and reliable monitoring. They are probably more useful for this application than are rain-monitoring radars.

The potential for further improving weather forecasts is now

available by measuring sea surface winds from space platforms, using active and passive microwave sensors. Knowledge of these winds is critical for understanding and forecasting weather patterns and developments.

The means by which such improvements could be achieved was indicated by an experimental study led in Canada by the Downsview branch of the Atmospheric Environment Service (AES). In this retrospective experiment, covering the Gulf of Alaska and the North Pacific, it was shown that the sea surface and wind maps obtained from the SEASAT satellite could be used to refine sea surface pressure maps based on in situ measurements. Particularly significant improvements could be made in the mapping of complex low-pressure weather systems that could not adequately be mapped by conventional techniques. Similar improvements have been made by other groups in case studies of other regions, notably the Indian Ocean.[1] Thus, although more research is needed, for instance, to expand the range of wind speeds that can be measured from satellites or to access the influence of rain, surface slicks and other factors on the imagery, the imagery presently available is sufficient to generate useful products.

Another example of the potential for improving weather observation through the use of satellites is the early detection of "trough deepening." This unique maritime weather problem is produced by an ocean-driven rapid atmospheric pressure drop, which can result in devastating snow storms that develop rapidly, creating major problems for coastal cities. Early storm warnings would allow street clearing operations to be prepared, and travel restriction warnings to be sounded before the storm arrives. The savings in snow clearing costs and traffic disruptions could amount to millions of dollars per year.

Much work must be done before the information gained from these experimental studies can result in fully operational systems for weather forecasting. However, it is not as formidable a problem as it might appear. The new generation of ocean monitoring sensors have been proved through use on the experimental satellite SEASAT and those in the NIMBUS series. No more than two (fully instrumented) polar-orbiting satellites might be needed to monitor the weather of the whole country.

Maps of Wave Conditions

At present, maps of wave conditions are generally developed using a combination of empirical models, based on wind measurements and on ship measurements; because ships generally avoid regions of high waves, the data they provide are biased. Clearly, satellite-derived sea surface wind maps will improve this process. However, the greatest contribution that satellite remote sensing can make in this area is the direct measurement of wave height, using active and passive microwave radar techniques. This direct measurement provides the most accurate technique available, particularly in cases where swells or gravity-induced waves from distant storms are substantial.

Synoptic mapping of "significant" wave height (the average height of the highest one third of the waves) would be very useful to shipping if it could be updated every 24 hours. While such updates may not currently be feasible, experience with instruments on the GOES-3 and SEASAT satellites suggests that measurements providing a wave height accuracy within approximately 1/2 metre could be achieved. Although significant wave height is measured only along a path directly under the satellite track, GOES-3 data from successive orbits have been used to map significant wave height over the North Atlantic at 1-metre contour intervals. The results compare favourably with surface observations. The remaining problem of producing daily mapping over all of the world's oceans would undoubtedly require several satellites to be in polar orbit at the same time. Nevertheless, the technique appears to be well understood, and it promises that, eventually, operational mapping should be possible once coverage can be obtained that is extensive enough and regular. It should be noted that a new, non-satellite technique is under development that also shows promise for the measurement of wave conditions; it is the over-the-horizon radar. A network, possibly combining land, ship and airborne radars, could provide an operational system; a cost/benefit study of such an approach may be warranted.

The dominant direction and length of waves can, in some circumstances, be estimated by using SAR. These estimates are particularly important in coastal areas where land forms and islands can distort and amplify wave patterns and forces. Through the analysis of

SEASAT SAR data, such effects have been successfully detected abroad, near Cape Hatteras and off Scotland. This wave information is useful where wave/current interaction has been suggested as the cause of unusually large waves.

Upper Ocean Currents

Descriptions and forecasts of upper ocean currents are very important to ship routing. It is through optimal ship routing that fuel consumption and distances travelled are reduced and ship safety is increased. Knowledge of ocean currents is essential for the determination of iceberg trajectories, which affects both shipping and offshore development. Knowledge of currents is important with respect to the location and tracking of disabled vessels. Similarly, information on ocean currents is used for offshore development, for predicting oil spill movements and establishing various hazards at specific drilling sites.

In situ measurement of ocean currents over vast areas is inadequate. Only satellites can cover the shipping lanes and offshore development regions comprehensively.

At present, satellite images of sea surface temperatures (SST) are used operationally to infer the position of ocean currents. Thermal "fronts," lines across which the temperature changes rapidly, often delineate the boundaries of major currents and can thus be used to locate them. The detection of major currents, such as the Gulf Stream, even at as low a resolution as 25 kilometres square, is extremely useful for commercial shipping, the coast guard and other applications.[2]

Satellite images of SST are widely used, both as research tools in their own right and to provide a background for the *in situ* point measurements made from ships. Direct transmission of this imagery from satellite sensors to ocean-going vessels seems possible, but has not yet been widely tested. The potential of SST maps in oceanographic research is, again, limited more by the lack of data processing facilities than by the lack of data.

To date, the infrared radiometer, which measures radiation emitted from the sea surface in the 10.5 - 12.5 micrometre band, has been used to measure SST. Another sensor, the coastal zone colour scanner (CZCS), has a wider range of wavelength sensitivity and a high

ground resolution of 1 kilometre. It was developed for ocean measurements, and has become available on the NIMBUS-7 satellite for this purpose. Both sensors, however, suffer from the same limitation—they require clear atmospheric conditions with no clouds.

The magnitude of the problem that this requirement poses is illustrated by the weekly maps, produced by the U.S. National Earth Satellite Service in Washington and by the Canadian Forces Meteorological and Oceanographic Centre (METOC) and the Atmospheric Environment Service, of SST features off the northeastern United States and eastern Canada. These maps have to be composed—usually by hand—from a mosaic of satellite images of SST measured at different times. Quite often, only a portion of the region is seen within a given observation period, while the remainder is obscured by cloud cover. Consequently, one half or more of the map may have to be extrapolated from observations compiled in previous weeks and augmented by reports from ships of opportunity. The compositions result in uncertainties of up to 100 kilometres in the position of the Gulf Stream and of thermal fronts. Over Canadian waters, such as the Grand Banks or along the Labrador coast, cloud cover is even more severe.[3] These limitations force many users to rely on expensive and very limited direct measurements from in situ systems.

Fortunately, "all-weather" radiometric techniques using the multichannel microwave radiometer (a passive radar) will be able to measure SST. SST with an accuracy comparable to that provided by the infrared sensors might be achieved in the near future. However, these techniques are under development and the data gathered thus far are still being analysed and assessed. As the problem of cloud cover is particularly vexing for Canada, our research efforts in this area should be intensified.

SST is only one way of measuring the location of ocean currents. Retrospective computer models for one class of currents (those that are wind driven) exist for many regions. Although limited at present by the absence of accurate wind measurements, these models might improve rapidly if satellite-derived surface wind maps became available.

The location, as well as the strength, of currents can also be

estimated from measurements of the slope of the ocean surface. To recall, the world is not exactly spherical; it is a geoid, with the oceans sloping up to 10 metres or more over distances of hundreds to thousands of kilometres. In situ measurements cannot measure this slope to the desired accuracy, but satellites will be used to apply altimeter data to the measurement of significant wave height and, possibly, the slope of the ocean. Although this method is in its preliminary stages, initial results are encouraging. Major currents, such as the Gulf Stream and the important, large-scale eddies and "rings," have been mapped on a grid scale of 25 kilometres using GOES-3 and SEASAT data and employing the slope detection technique. As more data are gathered, the accuracy of these estimates should improve, making possible the development of all-weather maps of surface currents based on ocean slope measurements produced by satellite.

Sea Ice Maps

The ability to monitor and predict the distribution and movement of sea ice is of considerable importance to Canada. As arctic and sub-arctic regions are opened up to marine transportation and exploration through projects such as the Arctic Pilot Project, the demand for accurate ice information will increase. It has been estimated that by the 1990s the value to Canada of such maps will run to hundreds of millions of dollars per year.[4]

Estimates of the extent of arctic shipping for 1985-2000 are provided in Table 1. Such shipping plans include, for example, the movement of grain from Churchill, Manitoba, and of iron, lead and zinc ores from mines in the high arctic. Accurate ice information will be crucial to the success of these projects. Drilling operations will also require ice information, not only to protect the drilling platforms, but to assist supply ship transits and to help oil spill contingency planning. Sea ice information maps can be used not only as pictures of local conditions around a drilling platform, but also as part of regional numerical models designed to forecast ice movement and the build-up of internal ice stresses, and for global weather modelling.

The maps of sea ice extent and ice type that are currently available have been sufficient for past Canadian requirements.

TABLE 1
ARCTIC ACTIVITY MATRIX —
ACTIVITIES REQUIRING ICEBREAKING SUPPORT

commodity/ mode type of activity	company or shipper	location/ route/origin	length of season	1985 return trips low/high	1990 return trips low/high	1995 return trips low/high	2000+ return trips low/high
crude oil by tanker	Dome et al.	from Beaufort Sea MacKenzie Delta	all year	43/48	48/120	48/240	48/335
crude oil by tanker	Globtik or Seatrain	from Prudhoe Bay, Alaska	all year	-/360	-/360	-/350	-/360
crude oil by tanker	Dome et al.	from Arctic Shell	all year	-/-	-/-	-/-	-/some
LNG by tanker	Panarctic & AGTL or TCPL	from Sverdrup Basin	all year	31/31	31/81	31/92	31/300
LNG by tanker	Dome et al.	from Beaufort Sea MacKenzie Delta	all year	-/-	-/24	-/312	-/312
LNG by tanker	Aquitaine	from Davis Strait	all year	-/-	-/-	-/50	-/50

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oil & gas drilling exploration & production	Dome	Beaufort Sea	all year	4/8	4/10	4/10	4/10
icebreaking support for drill, etc.	Dome	Beaufort Sea	all year	9/9	9/12	9/15	9/20
oil & gas drilling exploration & production	Panarctic Dome	Sverdrup Basin	Winter	4/5	4/10	4/15	4/20
oil & gas drilling exploration & production	Imperial Aquitaine	Davis Strait	Summer	2/2	2/3	2/4	2/5

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oil & gas drilling exploration & production	Imperial	Beaufort Sea	Winter	1/1	1/1	1/2	1/5
laying pipeline	Polar Gas	across McClure Str. & Union & Colonin S.	all year				
asbestos by ship	Van Omneson (Rotterdam)	from Deception Bay, Quebec	July-Oct.	6/8	-/8	-/8	-/-
lead & zinc ore by ship	Lloyds & M.V. Arctic	from Nanisivik on Baffin Island	Aug.-Oct.	8/8	8/8	0/8	-/8
lead & zinc ore by ship	Cominco & M.V. Arctic	from Arvik, on Little Cornwallis I.	Aug.-Nov.	8/8	8/18	8/18	8/18

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lead, zinc, copper & silver ore by ship	Texas Gulf Canada et al.	from Slave Province		-/-	-/-	-/14	-/14
lead & zinc ore by ship		from southern Keewatin District		-/-	-/-	-/-	-/some
lead & zinc ore by ship		near Fort Chimo, Quebec		-/-	-/-	-/-	-/some
iron ore by ship	Borealis Exploration Ltd.	from Melville Peninsula	all year	-/-	-/55	-/148	-/148
bulk grain by ship	Canadian Wheat Board	from Churchill, Manitoba	Aug.-Oct.	23/32	28/32	28/32	28/32

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petroleum & dry goods resupply	Chimo Shipping et al. & CCG	Eastern Arctic Route	Summer	34/34	34/38	38/40	38/44
petroleum & dry goods resupply	Northern Transportation Co. Ltd.	District of Keewatin Route	Summer	8/11	8/11	8/18	8/20
petroleum & dry goods resupply	Northern Transportation Co. Ltd.	Western Arctic	Summer				

Source: LIDEX, (1980) Labrador Ice Dynamics Experiment,
Newfoundland Institute for Cold Ocean Science,
Memorial University, Newfoundland

However, evolving exploration and development in the Resource Ribbon will require that our current ice information be substantially augmented by satellite remote sensing.

Although visible and infrared satellite imagery is occasionally used to make sea ice maps, these maps are usually prepared from ship observations and routine aircraft flights that use techniques such as side-looking airborne radar, photography and visual observations. The limitations of these techniques, including the absense of cloud cover required for the collection of visible and infrared satellite images, budgetary restrictions, the large physical area to be covered, the limitations of aircraft flights, and the paucity of shipping reports (most vessels simply must travel well clear of sea ice), all restrict the amount of ice information available today.

In many ways sea ice mapping is the archetypal remote sensing problem. Many sea ice areas are in darkness for much of the winter and are frequently covered with cloud in the summer. The area to be monitored is vast—about 11 per cent of the world's oceans are ice covered and a substantial part of this region is in Canada. Because most sea ice regions are remote and can change, in structure, dramatically,[5] in situ monitoring is expensive, difficult and often dangerous. Even when efforts are increased substantially, such as with the AIDJEX experiment in the arctic during the late 1970s, in situ monitoring can cover only a small area, and only for a short time.

Satellite remote sensing has been identified by many reports and surveys as the ideal technology for sea ice mapping. These studies have, in addition, attempted to determine what information on sea ice and snow is required.

In the United States, the efforts connected with the National Oceanic Satellite System (NOSS) provided the opportunity to focus on sea ice monitoring, as a part of the complete oceanographic satellite operation. The now-defunct $400 million project was aimed at a complete "end-to-end" system—from the development of sensors and spacecraft, through to the collection of raw data and the production of finished maps. The project was intended to provide a variety of oceans operation information, and would have met nearly all ocean information requirements. However, its high costs could not be funded.

In the Canadian context, the most important statements were produced by the Canadian SURSAT program (1977-1980). In considering how satellites might aid in surveillance, over the next two decades, of the 200-mile coastal fishing zone, the program identified the monitoring of sea ice as a priority for Canada.[6] Three levels of requirements were distinguished:

1. Planning: For the planning and design of sea ice operations, long-term statistical and climatological information is needed.
2. Strategic: Individual voyages and ice forecasting must be mapped on a daily basis.
3. Tactical: Support surveillance for individual ships and drilling platforms is needed on a nearly continual basis.

Canadian involvement in the study of sea ice by remote sensing from space is continuing, both by the private sector and by the Atmospheric Environment Service, through their involvement in the SEASAT and NIMBUS-7 programs. These studies include nineteen ice-related projects located in the Beaufort Sea, the Baffin-Labrador Seas, and the Gulf of St. Lawrence.

Unfortunately, it will be several years before a satellite, in a suitable polar orbit and carrying all of the necessary sensors, will be available for sea ice monitoring. Canada's options in this field should become clearer with the release of a major study, by Philip A. Lapp Ltd., on the applications of a Canadian radar satellite (RADARSAT).[7] Another feasibility study for RADARSAT is underway and it is estimated that it will take up to two years to complete. The satellite is scheduled for launch by 1988.

In all these studies, many important sea ice parameters have been established. They include the extent of ice coverage, the type of ice (new ice, first-year ice, multi-year ice, etc.), the thickness of the ice, the distribution and height of ridges, the extent and depth of snow cover, and the location and extent of leads and polynyas. The location, size and drift of icebergs, bergy bits and growlers are also important information for shipping, but, to date, have not been detectable from satellites. The optimum resolution for the identification of these parameters was estimated to be about 50 metres and greater resolution would be needed to identify smaller, but still dangerous, icebergs. Most

of the above information could be obtained from the proposed radar satellites. Sea ice mapping from space could, therefore, become operational before the end of this decade.

A facet of the proposed radar satellites that is realizable now is the multichannel passive microwave radiometer (SMMR), a form of radar designed for the sensing of sea ice. Although SMMR provides less detailed imagery, its relatively slow data rates make data processing manageable at much lower costs. The Ice Branch of the Atmospheric Environment Service is developing several promising techniques for the use of these data. For example, maps showing the distribution of multi-year and first-year ice have been drawn from data collected by the satellites NIMBUS-5 and NIMBUS-7.[8] Drawn on a grid of 25 kilometres, the maps provide regional (1000 kilometres x 1000 kilometres) models of ice distribution and movement. They could aid operators in the arctic with the plotting of ship courses, and could warn platform operators of ice conditions. In addition, they could be used for forecasting ice movement on a global scale, as needed for global weather modelling.

The less developed SAR imagery is also promising. With SAR it may be possible to differentiate between hard multi-year ice, first-year ice, and young ice floes, and it can be used to identify and track icebergs and other floating hazards. SAR is now routinely available on airplanes in some very limited regions.

However, additional research is essential before satellite SAR can be used for the applications. Development work is also needed to improve the registration of the SAR satellite imagery to geographic map co-ordinates. The enormous rate of data flow from SAR (in the order of 420 megabits per second) and its complexity present a major data-handling problem that will have to be solved before a satellite radar data system can be operational.

For the production of low resolution sea ice maps, passive microwave imagery is more than adequate. For higher resolution sea ice maps, however, a combination of SAR satellite imagery, which can view a large area, and side-looking airborne radar and airborne SAR imagery, which are capable of higher resolution, appears to hold the most promise for the foreseeable future. Unfortunately, until

appropriate satellite data are freely available or new systems are launched, ice mapping requirements will have to be met by existing airborne systems.

Coastal Mapping and Environmental Change

Much of Canada's long coastline is remote, ice-covered and subject to severe climate conditions. These factors make standard surveying and mapping techniques time consuming and expensive. The result is that substantial lengths of coastline have not been mapped to a sufficient degree of accuracy. Large portions of coastal waters have never had proper hydrographic surveys or charts, and little classification work has been done on coastal landforms or related biotic communities and coastal processes.

Coastal mapping and classification are related to transportation (as discussed in the previous section). However, they should also be considered separately, because of Canada's concerns about its sovereignty over arctic waters, the protection of its marine and coastal environment, and the development of energy and mineral resources. In the protection of these interests, Canada has established a 100-mile pollution protection zone for arctic waters, as well as the 200-mile fishery zone and jurisdiction over continental shelf resources off all its coasts. Development of Canada's resources, specifically through the offshore oil and gas exploration and the Arctic Pilot Project, requires accurate coastal and hydrographic maps. These cannot be produced within the allotted time without the aid of remote sensing techniques. This is an area in which satellite imagery is already being evaluated and which promises to be increasingly important in the future.

Canada is currently experimenting with a series of earth resources satellites, called the LANDSAT series. The Department of Energy, Mines and Resources, with assistance from the Canada Centre for Remote Sensing and the United States Geological Service, has used LANDSAT imagery to map barrier islands and to trace the development of washover bars and tidal channels. In recognition of the valuable data obtained from the program, Canada has named one of the arctic islands LANDSAT. The latest LANDSAT satellite (LANDSAT D) has higher resolution sensors and has profited from the advances in computerized

imagery processing. This satellite may be able to rapidly provide relatively inexpensive charts showing, for example, the coastline, islands, and shoals, and could be of significant value.

LANDSAT imagery has not yet been proved to be suitable for hydrographic charting, although its application in this area is promising. Hydrographic applications depend on the penetration of water by visible light in the blue-green range, which is limited to a depth of 20 metres. Although a depth of 20 metres is adequate for the draft of many vessels, LANDSAT could reduce the risks and costs associated with shipborne surveys if it could be used to map shallow waters. Even in turbid conditions, LANDSAT imagery could allow for the precise location of shoals and reefs and could be useful in the validation of old navigational charts. LANDSAT is limited by the requirement of clear atmospheric conditions, or fine weather. However, for hydrographic purposes, it could provide excellent imagery of seabeds that are shallow and that change slowly.

The SEASAT satellite has also demonstrated the great potential of SAR for coastal mapping and classification. Its excellent surface resolution could be further improved by the use of digital analysis and image enhancing techniques, in combination with information from other imagery. For example, the combination of SAR imagery with visible and infrared data from a multi-spectral scanner could result in the detection of surface features as small as 15 metres in length. Although it is uncertain at this point, some data suggest that the existence of important shallow water seabed features can be inferred from SAR data through subtle effects that can be detected from the surface.

SAR probably could not be justified for coastal mapping alone. However, it has many other capabilities for gathering real-time data on a variety of features, such as ice cover, offshore oil and gas activities in the Canadian arctic, and, possibly, shipping activity. It should be considered for this application as well.

Additional aspects of coastal mapping that are of importance include determining the oil spill vulnerability of coastlines and monitoring environmental change due to both erosion and human activity. Although monitoring is more easily and accurately done in

populated areas by aircraft and on land, the inaccessibility and size of the Canadian arctic require the application of satellite techniques. Potentially, regular coverage by satellites could provide an excellent method of monitoring coastline changes. Even fine-weather imagery, such as the visible and infrared, would be useful to monitor slow changes.

Detecting and tracking oil spills is vital to the protection of the environment and is an activity for which satellites might be used. The remote sensing techniques of airborne laser fluorescence (which causes oil spill particles to glow when laser light strikes them) and the satellite coastal zone colour scanner could be potentially useful in spill monitoring. SAR imagery may also be useful for this application by detecting reduced sea roughness in areas of large oil spills,[9] if the oil remains on the surface. However, if the oil does not remain on the surface, the usefulness of SAR imagery for tracking and detecting oil spills is greatly diminished.

The buoyancy of crude oil in cold water is so low that the oil may sink, rather than float as it does in warmer water. As changes occur in atmospheric pressure and in air and water temperature, the entire oil spill may sink and disappear from the view of the sensors, only to rise to the surface and reappear elsewhere when conditions change. This makes detection and tracking almost impossible.

Several recent studies have dealt with spill problems.[10] However, considerable research and development are needed before a reliable all-weather satellite system for oil spill detection could be available, and new sensing techniques will therefore be needed for arctic oil spill surveillance.

Fisheries

Although the fishing industry contributes only a small portion of Canada's gross national product, the fishing and processing industries are of considerable economic importance in maritime regions. Remote sensing can be useful to fisheries by improving the quality and safety of fishing activities, and by providing information to help in the effective management of fisheries. (Monitoring of the movement of the domestic and international fleets will be discussed in the following section.)

Safety was discussed in some detail in the section on transportation. In general, improvements in the present crude information about the state of the sea are needed, particularly in swell conditions where local winds are a poor indicator of sea state. Improved and more detailed surface wind information would also help fishermen to avoid storms.

Sea ice, particularly in the highly changeable conditions of the Labrador Shelf and Grand Banks, is responsible for damage to fishing boats and equipment every year. At present, sea ice mapping is very crude; improvements on any scale would find immediate use.

Certain types of fishing gear are susceptible to damage by high currents. For example, offshore trap fishermen try to avoid warm core eddies because the strong currents (50 centimetres/second or more) cause gear to be lost by submerging and deflating floats. With the exception of surface currents, all-weather measurement by satellite of the relevant parameters is now technically feasible, and needs only sufficient satellite data and processing facilities in order to become operational.

Several remote sensing techniques could also be used to enhance the efficiency with which fish are caught. Sea surface temperature can be correlated with fish type, rich nutrient regions, and areas of high biological productivity. Maps of isotherms, denoting sea surface temperature, could be produced in the near future by using data from infrared wavelength sensors and the all-weather passive microwave sensors (SMMR) of the NIMBUS-7 satellite; these data are already available. (The low resolution of the SMMR sensor might, however, limit the application of its data to fisheries.) The coastal zone colour scanner (CZCS), also carried on the NIMBUS-7 satellite, is capable of mapping surface concentrations of the green plant pigment chlorophyll. Because phytoplankton (freely floating microscopic plant life) contains chlorophyll, its presence may indicate food sources related directly to fish concentrations.

The Institute of Ocean Sciences is proposing a new Canadian passive sensor system that would be capable of measuring chlorophyll distributions in oceans, coastal zones, lakes and rivers.[11] This system would detect not only the radiance of water in reflected or scattered

visible sunlight (as does the CZCS), but also the additional component of visible light produced by the chlorophyll fluorescence that is stimulated by sunlight. This component is a well-defined and characteristic signature of chlorophyll occurring in the deep red visible colour range near 680 nanometres. The technique has proved successful in preliminary experimentation, and feasibility studies for satellite applications are in progress.

Accurate ice forecasting techniques could be applied to the northern cod fishery, which is currently underdeveloped. With daily or bi-weekly ice information, better capabilities for fishing in ice could be developed and the catch could be increased substantially. Accurate ice forecasts would allow the fishing season to be extended; even a one-week extension could be significant. And, as cod often concentrate close to the open sea/ice boundary, detailed ice information within, for example, 40 kilometres of the ice edge would be of value.

Yet another remote sensing technique—thermal imagery—could help fishermen in search of new species. This technique is presently utilized by Soviet fleets fishing for capelin off Canada's east coast.

Of perhaps even more importance than catching the fish, oceanic remote sensing could allow for better husbanding of ocean food resources for improved estimates of fish stocks. Although not yet fully proved, chlorophyll and isotherm mapping have promise for use in the production of monthly or bi-monthly phytoplankton biomass estimates. From these estimates spatial and temporal variations of primary productivity can be inferred. Such data are used in predictive fishery models. In addition, it is thought that drastic changes in nutrient concentration, indicated by changes in the colour of ocean water, may signal important conditions, such as over-fishing of an area.

Satellite remote sensing can augment the lower-level techniques, such as sonar, ultraviolet techniques, or seawater temperature measurements, being used and developed at present. Clearly, it could become one of the new and efficient tools of Canadian fishermen.

Surveillance

Potential applications of remote sensing to marine surveillance are of particular interest to Canada in view of the vast areas of coastal

waters and the continental shelf under Canadian jurisdiction. Surveillance can also be used as an effective deterrent to potential violators of Canadian Resource Ribbon control laws if the violators are aware that they are under surveillance. Patrol ships and aircraft provide this deterrent today, and with the aid of satellite imagery, the patrolling time required to detect, locate and track potential violators would not have to be increased. Satellites could observe domestic and foreign fishing vessels, offshore mineral exploitation activities on the continental shelf, and coastal and international shipping, and could provide defence surveillance.

A successful system would have to operate effectively under all weather conditions (the Grand Banks, for example, are seldom free of cloud and fog) and be able to provide near real-time data on a regular basis. These combined requirements (large area coverage, frequent updating, high resolution and all-weather capability) pose perhaps the greatest challenge to satellite remote sensing. Without very high levels of funding, it will probably be many years before we have sufficient satellite coverage and data analysis capability to fulfil these requirements entirely by satellite remote sensing. Nevertheless, the high cost of operating patrol vessels ($70 000 per day or $5 000 per hour) and aircraft ($4 500 per hour), and the number of these needed to fully cover Canada's Resource Ribbon, may well justify a spaceborne remote sensing surveillance system.[12]

It is certainly the case that further assessment of the technique is justified at this stage. SEASAT demonstrated that the SAR system may be able to meet some of Canada's surveillance requirements. Analysts, using SEASAT SAR, were able to detect vessels smaller than 100 metres in length on a systematic basis. For surveillance of continental shelf mineral resource activities, coastal and international shipping traffic, and fishing vessels, a SAR system could provide all-weather coverage at a resolution sufficient to detect all vessels in the domestic offshore fleet, as well as all foreign fleet vessels. SAR could be used to precisely locate offshore drilling and production platforms, to monitor supply boat traffic, and to ensure that other vessels comply with the safety zone surrounding each platform. SAR surveillance of shipping in the arctic, such as the system envisaged for the Arctic Pilot Project,

could aid in demonstrating Canada's management of the resources and the environment in that area, and in establishing Canada's sovereignty over arctic waters.

An alternative or complementary surveillance technique is acoustic remote sensing. The acoustic, antisubmarine networks, CAESAR and SOSUS, can be useful for the surveillance and tracking of all ocean-going vessels, once the sound print (which is analogous to a finger print) of a vessel is known. However, the security problem and cost of purchasing the sound print data are, at present, prohibitive for non-military users. Attempts should be made to assess the applicability of the data for civilian surface vessel surveillance and to improve accessibility. It may well be the case that non-Canadians have more information about our coastal zones than we do. Our national security demands that we redress the situation.

Climate Studies

A number of recent anomalies in seasonal climate (for example, the unusually harsh winters in eastern Europe and eastern North America) have focused attention on the importance of climate studies. The objectives of such studies include improving extended range (or seasonal) weather forecasts, attempting to make estimates of long-term (or decade-long) changes in the earth's climate, and establishing world climate models. These models can then be used to assess man's influence on the climate (for example, the effect of increased levels of carbon dioxide in the atmosphere). Satellite observations of the ocean, which can be made regularly and on a global basis, can be used to collect data for climate studies, and will likely have a revolutionary effect in that area over the next few decades.

Climate studies generally do not require that data values be taken over physically small regions (that is, a high resolution is not necessary), but they do need regular, large area coverage, with a measurement taken every twenty or thirty kilometres. Satellite imagery shows most promise for the measurement of net sea surface heat radiation, sea water/sea ice boundaries and boundary effects, upper ocean current patterns, sea surface temperature patterns, "upwelling" and "downwelling," surface winds and surface roughness.

To understand the effects that oceans have on the earth's climate, heat budgets of the upper layers of the ocean are needed. A heat budget is an account of all sources and losses of heat within the ocean, and between the atmosphere and the ocean. At present, only the approximate magnitudes of some heat budget components for a few areas are known. However, information on ocean heat radiation (infrared light), ocean currents, ocean-stored heat and ice cover, necessary for climatological modelling, can be acquired by satellite. The boundaries between sea ice and sea water, and the extent of ice cover that also play a major role in the world's climate could also be obtained by satellite. Monitoring the relationship of polar ice cap conditions to ice melting is of particular importance.

Full measurement of the relevant climate parameters will require careful integration of satellite remote sensing techniques with modern in situ measurement programs. Yet, several important air/sea conditions still will not be measurable from space in the near future. For example, sea level pressure may eventually be measured directly by satellite, by measuring total oxygen in air columns. At present, however, precision of only 1 millibar can be attained from ground measurements—or, over open water, from the satellite-derived surface wind measurements. Sensible heat flux between ocean and atmosphere can be satisfactorily estimated only if the air/sea temperature difference is known to a precision of 0.1 degree Celsius. At present, sea surface temperatures and soundings of air temperature from satellites are imprecise by at least one order of magnitude. Humidity flux can be estimated from space only indirectly, and then only at, not above, the sea surface. Clearly, more work at the oceans research level is required to resolve these problems before oceans operations can proceed satisfactorily. Progress in climatic studies therefore depends on integrated programs of satellite and in situ measurements.

In summary, this chapter has demonstrated how varied and multi-faceted the potential use of satellite remote sensing is for Canada. The multitude of beneficial applications recommends that this promising new technology be embraced as soon as possible.

Notes

1. The specifications desired by meteorologists–wind strength to within 2 metres/second and direction within 10 degrees–were nearly met by the scatterometer radar and passive microwave radiometer instruments carried by the all-weather, experimental U.S. SEASAT satellite. Similar information could be derived from the instruments of the experimental U.S. meteorological NIMBUS-7 satellite.
2. At higher resolutions–such as one kilometre squared–many surface thermal fronts that bound different water masses can be identified. These may indicate regions of high biological productivity where fish stocks concentrate. The accuracy of sea surface temperature measurements from these instruments is about 1.5 degrees Celsius, adequate for this purpose.
3. A good example of this problem is illustrated in Tang's (1980) study of the Gaspé current, which used satellite infrared images. His work depended on the fortuitous run of seventeen clear days in August; there were only four clear days in July, and five in each of September and October.
4. Projected from An Evaluation of the Utility of SEASAT Data to Ocean Industries, Final Report, SEASAT Commercial Demonstration Program, Vol. 1, 2 and 3. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, February 1980.
5. The detailed structure of sea ice can change significantly over a few hours: sustained ice-edge velocities of 25 centimetres per second or more can occur, and major cracks can open and close in a matter of hours.
6. Canada. Interdepartmental Task Force on Surveillance Satellites (1977).
7. P.A. Lapp, Private Communications, P.A. Lapp Ltd., Toronto, January 1981.
8. NIMBUS-7 is the only operational research satellite with sensors designed for oceanographic remote sensing. Although NIMBUS-7 data are gathered and processed by the U.S. Navy around the clock, access to them by potential operators and research users is

limited. They are often months old by the time they are received. Because they are considered research data, they are not dispatched with the same speed as operational data, which are provided within hours of collection.

9. See Vollmers et al. (1978).

10. Good examples are Johnson (1980), and Vollmers et al. (1978).

11. Jim Gower, Private Communications, Canadian Advisory Committee on Remote Sensing Oceans Working Group, Energy, Mines and Resources Canada, Ottawa, January 1981.

12. A number of reports have strongly recommended a selection of sensors and platform systems needed to patrol the Canadian Resource Ribbon with special emphasis on radar sensors. Noteworthy reports are: Satellites and Sovereignty (1977); the Interdepartmental Study Group on Ocean Information Systems (1979); and the SURSAT Program Final Report (1980).

Chapter Three
CANADIAN RESOURCES AND OPTIONS

In order to meet the multi-faceted Resource Ribbon challenge, Canada will have to mobilize all of the talent available. This section attempts to review briefly the Canadian and relevant foreign expertise available for this task.

Canadian Resources

There is a great deal of expertise in the field of remote sensing in Canada. The Canadian Advisory Committee on Remote Sensing, comprised of representatives from federal and provincial groups, universities and industry, co-ordinates Canadian remote sensing activities. The efforts of the government of Canada are co-ordinated and guided through the Inter-Agency Committee on Remote Sensing, which represents a score of government departments and agencies.

Among the groups and individuals in Canada that are active in remote sensing, the federal government's Canada Centre for Remote Sensing (CCRS) is the leading national agency. The CCRS serves federal and provincial agencies, universities, industry and the general public, and is involved primarily in research and development. The Centre assists in educating the remote sensing community, and develops new sensors and techniques for the processing and analysis of imagery. The CCRS is, in fact, the nucleus of the national program in remote sensing.

Provincial governments in Ontario, Quebec, Alberta, Manitoba and Nova Scotia have, in co-operation with the CCRS, established some of their own research centres. Their activities are similar to those of

the CCRS, with special focus on their individual needs.

The operational side of remote sensing that is relevant to oceans management is led by the Atmospheric Environment Service (AES) of the Department of the Environment. This involves the collection, processing, interpretation, dissemination and use of information on a regular basis. AES provides such routine data products as weather maps, temperature statistics, weather forecasts and global climate forecasts. The main users of these products and services are the Canadian Coast Guard, the marine fleets and the news media. AES also conducts an extensive research program of its own. Several other departments within the federal government are very active in remote sensing; Energy, Mines and Resources, Defence, and Fisheries and Oceans are just a few.

A score of universities in Canada are involved in remote sensing, with centres of excellence at the University of Calgary, Laval University, the University of Saskatchewan and York University. Four Canadian universities–Dalhousie University, Memorial University, the University of British Columbia and the University of Victoria–specialize in oceans applications. Unlike the government agencies, which are project oriented, the universities are freer to engage in a broad scope of basic research.

Some twenty or thirty commercial firms are also active in the field. The commercial community could be characterized by three areas of activity–satellite and sensor building, data collection and data analysis. The primary builders of sensors are SPAR Aerospace and SED Systems Ltd. McDonald, Dettwyller and Associates and Interra Environmental Consultants Ltd. are prominent in data collection, and several outstanding companies are experts in data analysis activities. Large oil companies, such as Dome Petroleum, Esso Resources, Gulf Canada and Petro-Canada, dominate the commercial use of remote sensing services.

Throughout the 1960s and 1970s, a sound scientific basis for oceanic observations from space was gradually established. In Canada, expertise in ocean studies is now merging with remote sensing to form the new field of oceanic remote sensing. Guided by the Oceans Working Group of the Canadian Advisory Committee for Remote Sensing, the

leading federal agency is the Department of Fisheries and Oceans.

The leading research laboratory for oceanographic studies on the east coast is the Bedford Institute of Oceanography in Halifax, Nova Scotia. Three federal departments participate in the Institute: Fisheries and Oceans (providing management and technical facilities support); Energy, Mines and Resources (Atlantic Geoscience Centre); and Environment Canada. The leading laboratory on the west coast is the Institute of Ocean Sciences, of the Department of Fisheries and Oceans, in Sidney, British Columbia.

Leading operational groups for oceanic remote sensing are the Meteorological and Oceanographic Centre (METOC) of the Department of National Defence, and the Marine Environmental Data Services (MEDS) of the Department of Fisheries and Oceans. METOC and MEDS, in co-operation with AES, routinely produce several kinds of ocean information.

Most Canadian groups that are active or interested in oceanic remote sensing are listed in Appendix D. They represent some 30 per cent of the groups throughout the world that are interested in remote sensing. The oceanic remote sensing groups tend to be located in populated maritime regions.

The Canadian remote sensing community, comprising several thousand professionals, is growing by leaps and bounds. Oceanic remote sensing experts, numbering perhaps a hundred, are emerging as a very active and vocal group in the remote sensing family.

Relevant Foreign Activities

Canadian work has not been conducted in a vacuum. The most significant efforts, in terms of funds invested and results produced, have been made by the United States. Although the U.S. agencies and commercial firms involved are too numerous to list in full, the leading agencies are the following: the National Aeronautics and Space Agency (NASA); the Goddard Space Flight Center in Washington, D.C.; the Ames Research Centre at Moffett Field, CA; the Jet Propulsion Laboratories (JPL) at the California Institute of Technology in Pasadena, CA; the National Oceanic and Atmospheric Administration (NOAA), with headquarters in Washington, D.C., and with many regional

facilities; the Environmental Research Institute of Michigan at Ann Arbor, MI; the National Marine Fisheries Service of NOAA, at Bay St. Louis, MS; the Woods Hole Oceanographic Institute, at Woods Hole, MA; and the Scripps Institute of Oceanography at La Jolla, CA. To sum up, the United States is unquestionably the world leader in oceanographic remote sensing.

The Soviet Union also has its own programs, but Canada has little knowledge of them. The European Economic Community's European Space Agency and the Japanese Marine Observational Satellite Program are international space programs of major importance.

Close international co-operation is vital to all these programs, especially in light of rapidly escalating costs. The proposed $400 million U.S. National Oceanic Satellite System (NOSS) is an example of how expensive some of the major systems can become. However, through co-operation, information can be shared and redundant expenses can be eliminated.

Canadian Options

Canada has three options for obtaining remote sensing data to manage its oceans and coastlines.

The first option is to extract the greatest possible use from existing Canadian and foreign satellites and airborne systems. High-quality data, collected by various agencies, are already available to Canadians. Canada has access to the LANDSAT polar orbit satellites, even though their sensors, which are designed and operated for land applications, have only limited marine use. Canada also has access to the geostationary weather satellites (GOES), but, again, they are of somewhat limited use for ocean-related applications.

More importantly, Canada has had access to ocean-oriented remote sensing satellites. Although the American SEASAT and TIROS-N satellites are no longer operating, Canada has regularly received the data from the NOAA series of oceanographic satellites. With NOAA-7 launched in the summer of 1981, these data will, we hope, continue to be collected. Data from the American experimental satellite NIMBUS-7 are also collected daily.

Several Canadian research groups, such as the Ice Branch of the

AES, and the Institute of Ocean Sciences, have been very successful in using these data for research purposes. Building on their achievements, Canada could make even more effective use of this information if it were received routinely from the United States. At present, however, only the U.S. Navy and NASA groups receive the NIMBUS data on a regular basis. If Canada favoured its first option, we would have to prevail upon the appropriate U.S. agencies to transmit the data to Canada regularly. Furthermore, we would have to arrange for the data to be transmitted as soon as it is processed. The U.S. authorities are willing to sell processed NIMBUS-7 data to Canadians if the need, as well as the commitment of resources (money, facilities, etc.) on the part of the users, is demonstrated. Alternatively, it might be possible to exchange finished Canadian data products for raw data from the U.S. sources.

Our first option (utilizing existing resources) is relatively inexpensive. It would require only the expansion of satellite ground facilities. Canada has its own satellite receiving stations, which are operated by the Canada Centre for Remote Sensing (CCRS) at Shoe Cove, Newfoundland and Prince Albert, Saskatchewan. The Department of Communications has receiving capability at the Shirley Bay Research Centre, and the Atmospheric Environment Service has satellite receiving stations at Vancouver, Edmonton, Toronto and Sondre Stromfjord, Greenland.

This considerable capability for ground data collection by Canada, coupled with the impressive capacity for airborne and in situ collection, could, if appropriately harnessed, produce a major step forward in oceans operations at a relatively low cost.

Canada's second option is to participate in the new satellite programs of other nations by sharing costs, expertise, data and results. In today's economic climate, major oceanographic satellite projects are not likely to be undertaken by only one country. The scrapping of the National Oceanic Satellite System (NOSS), in February 1981, is an example of retrenchment in this area. Canada could, therefore, opt either for full-fledged participation in major satellite projects or, better yet, could participate in projects only partially, and on a selective basis.

Partial participation is obviously less expensive. For instance,

Canada could piggyback Canadian oceanic sensors on the space platforms that are being prepared for launch in the next one to five years. Another possibility is that of the joint development of new sensors with other countries, on a financial or, preferably, barter basis. Several opportunities for such full-fledged or partial piggybacking have emerged.

Rising from the ashes of the NOSS project, NASA is now attempting to put sensors that were developed for NOSS projects (such as the radar scatterometer, passive microwave radiometer or colour scanner) on the next available NOAA satellite, which is to be launched after 1984. More remote, but still possible, is the prospect of putting sensors on the Dynamic Ocean Topography Experiment Satellite (TOPEX), which was proposed by NASA and which is under study for a 1986 launch. Other, even more remote possibilities are several as-yet-unfunded U.S. proposals. These include a pair of gravitation-measuring satellites (GRAVSAT), the wave energy/water/ice SAR satellite; and the major cryosphere-sensing ice/snow/glacial/water/climate sensing systems of the Ice and Climate Experiment (ICEX).

The Space Shuttle, which can be seen as a short-term space platform, also has some oceanic remote sensing potential. Several of the Shuttle facilities could be used for Canadian sensors. The sensors could be put into the Shuttle Space Lab for short operation, and the Canadian-developed remote manipulator, CANADARM, could be used for launching the mini space platforms with our sensors. In addition, Canada could rent space in the cargo bay for operations of self-contained sensor packages.

The piggyback approach is not limited to U.S. programs. The French Space Agency is funding the planning stage of an earth-orbiting satellite, SPOT, which will be primarily a land sensor system. This satellite system is planned for launch in 1984. Other possibilities include the Resource Satellite (ERS-1) of the European Space Agency, and the Preparatory European Remote Sensing Project, which is proposed for the late 1980s. Japan is also conducting a feasibility study for a Marine Observational Satellite (MOS) program involving the launch of at least three satellites in the mid to late 1980s. Canada is following the MOS project closely, and the possibility for further co-

operative programs exists. The international co-operative SARSAT program, which involves the U.S.S.R., France and the United States, offers yet another example of this approach.

The piggybacking approach seems, therefore, feasible. However, extreme caution would have to be exercised if this option were to be implemented as the risks that the foreign satellites will, indeed, be put into orbit are considerable. While all of the space programs are funded to some degree already, some will likely not be completed in the foreseeable future.

The third option for acquiring satellite sensor systems and data production facilities is for Canada to build them on its own, and to try to attract other countries to piggyback on its programs. Throughout the 1960s (with the ISIS series of research satellites) and into the 1970s (with the communication satellites), Canada gained considerable experience in satellite design, building and instrumentation, as well as in the design, construction and operation of receiving stations and in data processing, interpretation and display.

As mentioned previously, several studies are in progress that are investigating the possibility of a new all-Canadian satellite, called RADARSAT. Sensor selection and applications are under review, with synthetic aperture radar as the primary sensor and a scatterometer and radiometer high on the priority list. Several U.S. agencies, as well as others, have already shown interest in the satellite. The participation of such agencies in co-operative international programs, in which Canada took the lead, could be helpful in funding and implementing an operational RADARSAT program.

Developing our own sensors and space platform would not entail that we develop our own launch vehicles. In fact, Canada has relied on foreign rocket launching facilities in the past and will continue to do so in the foreseeable future. A non-traditional launching facility for our space platforms is presently available through the Space Shuttle, and is much less expensive that those previously used. Hence, Canada could, and should, make use of the Shuttle whenever possible.

The first option, that of employing existing facilities, comprises the major thrust of current Canadian oceans research and oceans management. Unquestionably, this route should not be abandoned. The

second option consists of piggybacking, with cost-sharing between nations. This is a new approach for Canada, but it is attractive in terms of reducing costs, despite the fact that it involves many compromises. Every emerging opportunity should be thoroughly investigated and, if it can be of benefit to Canada, should be carefully exploited.

However, if Canada wants to control and maintain its sovereignty over the entire Resource Ribbon, we might well have to employ the third, and most expensive, option—placing a completely Canadian sensor system in space. Monitoring all of the Canadian arctic, as well as all of the east and west coasts, requires satellite orbits, sensor-viewing orientations, and sensor designs that are unique to Canadian needs. Neither the first nor the second option will be fully adequate to provide for these needs, even if employed to their fullest extent.

These, then, are the three basic options available to Canada for acquiring satellite sensor systems and data production facilities for oceans remote sensing. The range of tasks to be performed by remote sensing techniques suggests that no single option can meet all of Canada's needs at sustainable costs. All three options will, therefore, have to be considered and, to varying degrees, exploited.

Chapter Four
AGENDA FOR ACTION

The previous chapter has reviewed the resources and options available to Canada to enable it to adequately face the Resource Ribbon challenge. Which of these three options will be preferred is not yet clear. Although some combination of the options would, in fact, be the most appropriate response to the challenge, it might be several years before a definitive course of action will emerge from the public policy debate.

On balance, oceanic remote sensing technology in Canada seems to be in good shape. Considering the economic situation of the country, the levels of funding and attention that have been given to oceanic remote sensing have been quite adequate. Naturally, current Canadian efforts in the development of hardware technology (such as sensors, platforms, and ground stations) should be further supported. Similarly, the training and employment of scientists and technologists at all levels should continue to increase. However, although the state of this technology has, to date, been adequate, this is not the case for oceanic remote sensing in Canada as a whole.

After reviewing oceanic remote sensing in Canada, after analysing the possibilities of this type of sensing for observing our Resource Ribbon, and after assessing the existing and potential technological capabilities, one broad conclusion has emerged. Regardless of which combination of options is eventually selected, a substantial improvement of one aspect of the existing situation could be made immediately by focusing on the weakest aspect of the oceanic

remote sensing effort in this country–data management and the production of data products.

The Data Management Situation in Canada

At present, there are no data archival and retrieval systems for remote sensing ocean information in Canada. Facilities for data inventory and quality control are practically non-existent.

There are several groups that can store limited amounts of specific oceans data. The Canada Centre for Remote Sensing has accumulated a great deal of LANDSAT imagery. Yet, another centre of excellence in remote sensing, AES Downsview, has no facilities to store any of the digital weather satellite data that it collects daily. With the exception of the efforts of METOC and MEDS, no major system exists at present to house or disseminate oceans satellite imagery. This is one of the principal reasons why user access to remote sensing data is severely limited.

Complicating the handling of data are the volumes of information generated by satellite sensor systems, especially by systems like the Synthetic Aperture Radar (SAR). Storing, cataloguing and updating this information, as well as devising ways to compress, compact and simplify it, have emerged as critical problems.

Another problem with data is that they come in various shapes and forms and handling of the data is not yet uniform. The need for national standards and guidelines for data archiving has become pressing.

The recognition that data management–the collection, processing, compacting, dissemination and archival storage of remote sensing data–is becoming of pivotal importance has already been emphasized by several American and Canadian reports. These include the Ice and Climate Experiment Report for NASA; the Ocean Information Services Study for the Department of Fisheries and Oceans; the SEASAT Commercial Demonstration Program Final Reports for NASA; the P.A. Lapp Report on Ocean Information Systems for the Ministry of State for Science and Technology; and Information for Coastal Zones Decision-Making for the government of British Columbia.

As stated previously, data are of limited use by themselves, and

must be transformed into information products. Several such products —sea surface temperature maps and wave and wind charts—are very close to being routinely available. Other products, such as ice-concentration and ice-type maps derived from NIMBUS-7 microwave data, are still being researched, and the processing of SAR data will not be possible for some time. All of these projects require that attention be refocused on producing information products that are usable by both the public and private sectors. Data products will have to meet user requirements, and data management personnel will have to be responsive to user needs.

To conclude, Canada finds itself in the situation of a "technological push." The hardware technology is available and is generating data that are now plentiful and may soon become overwhelming. Therefore, the authorities must now focus their attention on data management and the production of data products.

The Proposed Awareness Program and a Data Management Facility for Canada

The foregoing points lead to the following major proposal: that Canada establish a facility with a mandate to advance oceans research through the computerized management of oceans data. Its fundamental goal should be the creation, the development and, where useful, the dissemination of user products for oceans operations. A primary function of this facility would be to provide data archives in order to allow the storage and retrieval of up-to-the-minute, real-time data and current year data, as well as historical data.

The proposed facility should complement, rather than compete with, those institutions that are already involved in oceanic remote sensing. Appropriate refocusing of these institutions to ensure that necessary work is done with a minimum of redundancy would help keep additional funding to a minimum. The data management facility itself should concentrate on transforming the results of existing efforts into useful operational products. It is essential that the management of such an entity involve the participation of all interested parties. Overall guidance by the government of Canada is imperative, but provincial representation is also necessary to ensure that local needs

are met. The two senior levels of government would be the most appropriate parties to guide the effort, since they are in the best position for policy formulation, direction of the system towards its goals, and fund stabilization. Most goal-oriented research is carried out by government laboratories. However, the cutting edge of basic, or general, oceans research is done by the universities, and, due to their knowledge of the development of oceanic remote sensing, they should be involved in the management of the new facility as well. Private sector involvement is also essential to ensure an emphasis on usable end-products. Private firms may eventually find it worthwhile to produce commercial spin-off products on their own, further to those originally developed by the facility.

The first task of the facility will be to inform potential users of the information products that are available. This awareness program should occur simultaneously with, if not before, the creation of the facility. A network of agents to develop expertise and advise on the accessing of ocean information sources (mentioned in detail in the next section) might be set up to introduce potential users to oceans information and its applications. Through these agents, users could convey constructive criticism to those responsible for developing the data management system, thereby contributing to its ultimate form.

Based on the demand expressed, various configurations of the data management facility might emerge. The existence of oceanographic communities, both on the east and west coasts, indicates that data management facilities might be desirably located in these areas. However, the location and development of the system cannot be based solely on expressed demand. Oceanic remote sensing should be applied to Canada's entire coastline—not only to the east and west coasts, but also to the hitherto neglected, and most promising, arctic coast. In fact, a facility located in central Canada might provide the required neutrality, and might best blend the interests of potential users with those of the federal and provincial governments, industry, and academia.

Three alternatives thus offer themselves: twin centres on the east and west coasts, a triad of centres (in western, central and eastern Canada), or one central facility. Each alternative undoubtedly has its

advantages and disadvantages. However, a facility located in the centre of the country seems to be preferable at this stage, as it would be available for the lowest cost.

The acronym MAGIC, for Marine, Academic, Government and Industry Centre, has been proposed as a title for the central facility. Although a full cost-benefit analysis for MAGIC will be required, the following is a preliminary cost estimate for the start-up of such a facility:

Capital Expense:		$ Millions (1982)
Building: 4 000 sq. m. x $750/sq. m.		3.0
Land: 3 acres on a university campus, nominal $1		0.0
Computer equipment:		
Mainframes	2 x $800 000	
Processor and Displays	2 x $800 000	
Mini system	$300 000	
Peripherals	$300 000	3.8
Product development equipment		
(colour printers, photographic, mapping)		1.0
TOTAL CAPITAL COSTS		7.8

Operational Expenses:		$ Millions (1982)
Personnel: 15 professionals x $50 000 per year		
30 support staff x $35 000 per year		
5 management x $60 000 per year		2.1
Maintenance Building: $100/sq. m./year	($400 000)	
Maintenance Equipment: 10% year	($320 000)	
Expansion of Facilities: 20% year	($620 000)	
Equipment Replacement: 20% year	($620 000)	2.0
TOTAL OPERATIONAL COSTS (per year)		4.1

Some additional costs would be accrued, as key users, such as the Atmospheric Environment Service, the Bedford Institute of Oceanography, the Institute of Ocean Sciences, York University and the University of British Columbia, and others would have to expand their operations for participation in this program.

These costs would not have to be borne by the governments alone, as direct economic benefits will flow from the application of the oceanic information systems described. If appropriately introduced,

these benefits will be recognized by potential users. A strategy to effect recognition of this potential is, thus, crucial, for only then will the users be willing to share the costs.

The "user-pay" principle should be applied to the beneficiaries of oceanic remote sensing information in order to cover a substantial portion of the operational costs. In fact, financing for the operation of MAGIC should come, in part, from the direct sale of products to users. In this way, MAGIC will be forced to maintain practical applications as a top priority. The user-pay concept is fundamental to the long-term viability of the proposed system, and would protect it against any unforeseen withdrawal of government support.

Seed financing for the MAGIC facility can be obtained from a strategic grant of the Natural Sciences and Engineering Research Council of Canada (NSERC). In addition, if a facility were located in the Province of Ontario, and if it were established with a major industrial component, the provincial BILD program could provide support for the facility.

As has been demonstrated previously in this report, a facility such as MAGIC would produce various benefits for Canada. By financially supporting part of a data management system, as well as the related awareness program, Canadian governments could produce, from remote sensing imagery, information that would be utilized in oceans management and for surveillance. Products could be made available on a daily or weekly basis, and might include ice mapping, glacial movement and iceberg drift charting, ocean current mapping, sea surface temperature mapping and contouring, in situ buoy and acoustic data, and ocean and fishing fleet charting. Reaction from user groups suggests that these products are in demand and are highly saleable. Among the principal customers would be oil companies working offshore.

Financial benefits would also be a product of a program such as MAGIC. As mentioned above, the value of sea ice mapping alone is estimated to be in the order of hundreds of millions of dollars and adequate airborne surveillance of Canada's Resource Ribbon is thought to be worth another hundred million dollars annually.

A rigorous cost-benefit analysis is a necessary part of the

assessment of the proposed oceanic remote sensing program. A preliminary calculation indicates that the benefits, conservatively estimated, could be in the order of hundreds of millions of dollars annually. This would be the case even with the predicted additional capital cost of approximately seven and a half million dollars for building a new centre, and with yearly operational expenses of about four million dollars.

In this light, even the most expensive of Canadian options—launching our own oceanic remote sensing satellite while also pursuing the two other options cited—would seem to be justified. In conclusion the Canadian governments, as well as the private sector, could finally start to reap real benefits from their considerable investment, accumulated over the years through various projects, of tens, if not hundreds, of millions of dollars.

Further Major Recommendations

Most raw remote sensing information from ocean surveillance systems is presently of little use to much of the user community. Data must be transformed into a product of direct interest and utility to government and private users if they are to be of value. In light of this, we offer the following four major recommendations.

Recommendation One

More attention should be paid to the nature of remote sensing information products and to their relevance to specific users. This function should be performed by an operational computerized remote sensing Oceans Information System (OIS), to be housed in MAGIC. The objectives of an OIS would be as follows:

- Rapid procurement, cataloguing and data-base management of all remote sensing information. Data-base management includes preliminary processing, retrieval and analysis, as well as archival services and dissemination of the information.
- Production of high-quality products, tailored to users' needs.
- Development of information delivery systems to ensure that users are faced with as few technical, procedural and administrative hurdles as possible.

- Establishment of procedures to relay the needs of users to actual operators of remote sensing systems.

Recommendation Two

A system of "extension agents" should be created to demonstrate to users the exact procedures and applications of oceanic remote sensing products. Agents would spend enough time with each user to ensure their comprehension and ability to apply oceanic remote sensing products to their needs. In addition, agents would relay to MAGIC the interests and recommendations of users. A continuous dialogue between agents and users would assure that the users pay only for the information that is of value to them.

Recommendation Three

Marine remote sensing information products, as well as the processing hardware and software, should be recognized as marketable commodities of international significance. These technologies and/or information products could be marketed to other countries. This would be co-ordinated through the Department of External Affairs and the Department of Communications, as well as through the Canadian International Development Agency; however, these procedures require further examination within the contexts of the Law of the Sea debate and the North-South dialogue. In addition, the development of the talents and technology that would be marshalled in the operation of a high-order Oceans Information System, while already justifiable on the basis of their value to the national interest alone, represents exciting international opportunities. Exchanges could be made that would include the flow of human, as well as material and financial, resources. The training of experts in oceanic remote sensing could represent a unique Canadian contribution to the transfer of technology to developing countries.

Recommendation Four

The ability to manage complex information systems is, and should be recognized as being, in the national interest. Canada does not have the large military systems which, for instance, the United States or France

could mobilize to expand their technological capability in the frontier of information technology. The proposed Oceans Information System would offer Canadians an opportunity to develop expertise with complex systems in an essentially peaceful application. Mastery of this technology could then lead to other large-scale applications, thus providing impetus for the growth and advancement of the Canadian electronics industry.

Technical Recommendations

Several technical recommendations, which relate to existing remote sensing and in situ programs, must also be brought forward.

1. Regardless of which changes in remote sensing technology are introduced, Canada should make greater use of existing satellite and ground receiving processing facilities. Acquisition of data from LANDSAT D, NIMBUS-7, GOES, and NOAA-7, -8, and -9 should be facilitated. Where appropriate, these data should be obtained routinely and disseminated rapidly.
2. (a) Data from alternative systems, particularly in situ instrumented buoys, should continue to be gathered. These data should be made available through MAGIC facilities. Consideration should be given to expanding the buoy coverage of our coastal zones, as well as to improving and expanding the buoy-to-satellite-to-land communication links for data collection.

   (b) Providing that the difficulties between the military and civilians can be resolved, acoustic data from in situ systems, such as SOSUS, should be made available.

   (c) More careful examination and integration of data that result from existing and planned airborne data systems is needed. The addition of new oceanic information gathered by systems such as side-looking airborne radar (SLAR), coastal zone colour scanners (CZCS), push-broom scanners, and fluorescence line imagers (FLI) operated from existing routine air patrols, should also be considered.
3. Canada should increase its co-operation with and participation in international space programs—especially those of the European Space Agency and the Japanese Space Agency—in order to attain

the level of effort being devoted to Canada-United States programs. This diversification will ensure that Canadians are in a position to obtain oceans data from all existing and planned sensor systems.

4. The design and applications of graphics display systems, and their integration into data management operations, should be investigated, and systems that can produce needed data products should be developed. Priority should be given to the development of information products that suit the needs of users.

Conclusion

In conclusion, Canada has the largest area of coastal Resource Ribbon of any country on earth. Canadian sovereignty and, indeed, a large part of Canada's economic future may depend on the management of this vast resource. To this end, Canada should use the new oceanic remote sensing technology to its fullest potential.

By developing policy and providing funding, federal agencies have taken the lead in identifying the areas of oceanic remote sensing research and development that are of critical interest to Canada. Following this lead, remote sensing technology (that is, sensors, platforms, telemetry, earth receiving/recording stations, and imagery analysis/processing) has, through the combined efforts of all groups active in the field, been extensively developed. The challenge to the oceans management community, now, is to utilize this new source of oceanic information effectively.

Various options for obtaining more oceanic remote sensing information have been outlined. In any case, our ability to respond successfully to the Resource Ribbon challenge depends upon our success at mastering data management. If this weak link is strengthened, Canadians will have the expertise and technical means by which to become not only managers of the activities in our Resource Ribbon, but also world leaders in oceans and coastal zone management.

Appendix A
REMOTE SENSING IN HISTORICAL PERSPECTIVE

Evelyn L. Puitt, of the Office of Naval Research, Arlington, Virginia, coined the phrase "remote sensing," but the field is not as new as one might think. Although it was not called remote sensing, the invention of photography in 1822 created the first "recording sensor," and the first "near space" flight—balloon photography of the city of Paris—took place in 1856. Aerial photography of Rome by Wilbur Wright followed in 1909. High-altitude photography, first carried out in Germany, used rockets to photograph the ground.

Rapid technological advancement often occurs during times of war, and the field of remote sensing is no exception. The American Revolution (1795-1781) saw the use of balloon reconnaissance; by 1914 aerial surveillance was being used. Efforts during the Second World War developed microwave and radar remote sensing to facilitate high-altitude bombing through clouds. It is these types of systems that show the most promise for modern oceanic sensing today. Between 1914 and 1939, several new methods of in situ remote sensing were invented; these included acoustic detectors and seismic sensing of geological movements in the earth, radio and radio location, and rudimentary radar.

The development of modern remote sensing began in the years immediately following the Second World War and was based on a number of electronic and optical technologies developed during the war. Some of the more important developments were Side-Looking Airborne Radars (SLAR); black and white, colour, and infrared photography;

vacuum tube photo-electric detectors to convert light directly into electrical signals; digital computers; and solid state electronics (based mostly on silicon), including transistors and their large-scale integration on ships (ICs). The use of ICs has vastly reduced power requirements for remote sensing devices. Today, excellent imaging detectors (called CCDs) exist in which more than 100 000 picture elements, or pixels, are fabricated on chips of silicon no larger than five square millimetres.

The solid state electronic technologies and their low power requirements permitted a breakthrough of great magnitude—remote sensing from space. An exciting new era of satellites powered by solar cells (another revolutionary solid state device) began with the launch of the Soviet satellite, SPUTNIK 1, in 1957. As many countries entered the space race, a major step in remote sensing from space was the development of weather satellites, beginning with TIROS-1 in 1960 and continuing with the NIMBUS and NOAA series today. The early weather satellites produced coarse images of cloud patterns that were sufficient for forecasting, but images of the earth were indistinct. At present, nearly all of the modern remote sensors that view the earth from space involve developments based on weather satellite technology.

The future utility of remote sensing from space became apparent during the manned space flights of the 1960s, MERCURY, GEMINI and APOLLO. The astronauts used optical photographic methods to perform several earth resource remote sensing tasks. The quality of the imagery they produced demonstrated the potential for observing the earth, its oceans and its coastlines from space.

Remote sensing from space matured during the years 1961-1981. Surveillance from space may be strategic, requiring repeated observation of wide areas over a long period, or tactical, requiring individual observation of small areas on relatively short notice and calling for high resolution, rapid sensor deployment and localized target areas. The difference between strategic and tactical operations lies in the frequency of observation repetition and the degree of imagery resolution required for each. An explanation of remote sensing methods may be helpful at this point.

Remote sensing may be either passive, in which case natural radiation from the earth's surface (reflected sunlight or surface

radiation) is sensed, or active, in which case radiation, originating from an illumination source on the spacecraft, is reflected from the desired point on earth and is detected by sensors on the spacecraft. Active sensing employs either radar or laser systems, both of which involve single frequency sources of illuminating radiation. Passive systems employ several sensor elements to cover the individual wavelength bands for each component of interest across the visible, infrared and microwave regions.

Passive and active systems may be imaging or non-imaging; they may produce a picture or image of the target area or may just detect and measure radiation originating from it. In each case, however, the modifying effects of the intervening atmosphere must be taken into account before quantitative inferences can be made. For example, atmospheric constituents such as molecular oxygen, carbon dioxide, water and aerosols, and atmospheric conditions such as temperature, humidity and turbulence can all affect the transmission of radiation through the atmosphere.

The selection of sensors for performance, operational ruggedness, reliability and the range of wavelength sensitivity depends upon the surface to be observed, the platform being used and the phenomena under study. Many effects are best sensed at specific wavelengths of the electromagnetic spectrum (ultraviolet, visible, infrared or microwave). Normally, radar and microwave remote sensing can be operated around the clock and in all weather. However, visible and infrared remote sensing are usually only operable in the absence of clouds, and visible sensing is further restricted to use in daylight only.

Over the past two decades, advances in the technologies of sensor platforms, sensors, telemetry, ground recording and data processing have provided the capability for high-quality remote sensing from which reliable diagnostic information can be inferred. These technologies are in use and are effectively applied to many commercial, domestic and military tasks. However, they also have great potential for further applications.

A study of earth resources satellites began at NASA's Goddard Space Flight Center in 1967 and culminated in the development of the first Earth Resources Technology Satellite (ERTS-1), launched in July

1972. From an altitude of about 900 kilometres, ERTS-1 produced detailed (900 nautical miles x 900 nautical miles) pictures of the earth between 1972 and 1974. These pictures, in four wavelength bands (green, yellow, red and infrared), were transmitted to a number of earth receiving stations for production and distribution. The Canadian Centre for Remote Sensing has made extensive use of this imagery to develop prototypical information products. Use of the Earth Resources Experimental Package on the manned spacecraft SKYLAB-A (1973) provided detailed imagery of many parts of the world, although its orbital dynamics limited observations to those between 50 degrees N and 50 degrees S.

These manned space flights laid the foundations for the latest breakthrough in the deployment of hardware systems for space: the Space Shuttle. The Shuttle's maiden flight, on 12 April 1981, heralded a new ear for remote sensing space exploration. The remote sensing tasks being proposed for the Shuttle are derived from the earlier SKYLAB missions. Canada is in the forefront of this technology, with planned satellite launches and the design and fabrication of the Canadian remote manipulator.

A range of space platforms has been developed in the U.S.S.R. The SOYUZ spacecraft have shown progressive improvement and the modular assembly of an orbital space station (SALYUT) is a major part of the Soviet space effort. In this respect, the programs of the United States and U.S.S.R. show great similarities.

Another early (1975) space station experiment that had remote sensing components was the joint U.S./U.S.S.R. APOLLO-SOYUZ Test Project (ASTP). Unfortunately, the quality of the images was not very high, as hand-held, 35- and 70-millimetre cameras were used. Several of the other APOLLO missions produced useful photographic imagery, however. The manned missions demonstrated that trained astronauts could obtain useful, and sometimes unique, earth resource photographs. They also illustrated how important the presence of human observers was, as, for example, in the siting of internal waves seen in sunlight patterns (reflections of sunlight off of water).

Appendix B

PRINCIPAL OPERATING SATELLITE SYSTEMS AND THEIR TECHNOLOGIES

Three operational satellite systems have applications to oceanographic and coastal zone monitoring. They are weather satellites (for example, NOAA, GOES, NIMBUS, GMS, TIROS, METEOSAT and DMSP), earth resources satellites (LANDSAT and EXPLORER) and multi-use space platforms (such as the Shuttle and SPACELAB). Weather satellites provide more frequent area coverage—at least twice a day—which is necessary for short-term weather forecasts, but the area covered is quite large and the picture resolution is low. By contrast, earth resources satellites provide infrequent coverage (once every eighteen days at the equator for LANDSAT), cover a small area, and have a high resolution.

The necessary trade-off between high resolution and frequency of coverage means that neither type of satellite is ideal for monitoring all of the phenomena associated with coastal zones. Polar-orbiting weather satellites are primarily valuable for measuring sea surface temperature and for ice forecasting. However, as Hussey and Heacock (1978) have pointed out, they are also useful for fishery and hydrological applications, traffic monitoring, shore surveillance, oil spill monitoring and in other areas. The high resolution remote sensing satellites are particularly suited for these applications, but the infrequency of coverage restricts their operational usefulness.

Weather Satellites

Four distinct types of North American weather satellite are in

operation today. Their main task is to provide information from cloud-top pictures for short- and long-term weather forecasts.

The NOAA (National Oceanic and Atmospheric Administration) satellites are in near-polar, sun-synchronous orbits (that is, they cross the equator at the same local sun-time). They pass every area of the earth at least twice a day, and cover a swath of 2 000 kilometres at the equator.

The GOES series of satellites, also operated by NOAA, are geostationary--they remain in a fixed position with respect to the earth. Their main application is strategic weather forecasting, and they cover an area centred about the equator that spans 120 degrees of latitude and longitude. The Japanese also have a geostationary satellite, METEOSAT, which is providing valuable data for weather forecasting.

The NIMBUS series of weather research satellites are operated by NASA for the testing of new sensing systems, including radar. They are polar orbiting and sun synchronous. Two sensors of particular interest carried by NIMBUS-7 are the coastal zone colour scanner (CZCS) and the Scanning Multi-frequency Microwave Radiometer (SMMR). The SMMR provides high-quality information from which ice type (first year, new, or multi-year) and ice concentration can be assessed and from which ice maps can be plotted. Sea surface temperature mapping and ground snow cover are two other areas to which SMMR data might be applied. These data can be used in forecast models and, eventually, routine ice forecasting services may be possible. Unfortunately, NIMBUS-7 is planned as the last in this series of satellites. New satellite systems, such as Canada's RADARSAT, which is now under development, should provide these data for future work.

Finally, the U.S. Air Force operates the Defense Meteorological Satellite Program (DMSP) satellites. The future of this program may be in doubt, however, as most of the satellites are inoperative.

In Canada, the Atmospheric Environment Service (AES) of the Department of the Environment is responsible for the reception, analysis and dissemination of weather satellite data. Some of the satellite-derived data are useful for sea-state determination and ice forecasting, both of which are important for the monitoring of coastal zones. AES operates ground receiving stations in Vancouver, Edmonton,

Toronto, Halifax and Sondre Stromfjord, Greenland. The station in Greenland is intended to receive data for the regions of Baffin Bay and Ellesmere Island. The active weather satellites used by AES are NOAA-6, GOES-EAST and GOES-WEST. The most recent addition, NOAA-7, was launched on 23 June 1981.

Remote Sensing Satellites

The special-purpose satellite of the Heat Capacity Mapping Mission (HCMM) was the first of a series of small, inexpensive Application Explorer Missions (AEM) conducted by NASA. These "budget satellites" have less precise orbit accuracy and stabilization than the larger satellites and are intended for feasibility experiments. The AEM-1, launched on 26 April 1978, was the first spacecraft built to test the feasibility of measuring the thermal variation of earth surface features in order to infer their identity and condition. Although it is designed for land use, these capabilities might well be applied to coastal zone monitoring.

SEASAT-1 was a proof-of-concept research satellite and was oriented towards proposed operational oceanographic research. On 26 June 1978, it was launched into an 800-kilometre, circular, near-polar orbit. The satellite was designed to provide alternating day and night coverage as often as every thirty-six hours for some of its sensors. Approximately 95 per cent of the earth's oceans were to be covered by the satellite. Unfortunately, system failure occurred ninety-nine days after launch, limiting the data produced by the satellite. However, the data that were obtained were of such high quality that they are still undergoing extensive assessment for planning future satellite systems and system applications.

An important new sensor, which was on board SEASAT-1, was an L-band (22cm) Synthetic Aperture Radar (SAR), designed to generate imagery, both by day and by night and in all weather conditions, across a 100-kilometre swath (from 230 kilometres to 330 kilometres to one side of the subsatellite track) with 25-metre resolution. SEASAT also carried a microwave radiometer (SMMR) that was identical to the one used on NIMBUS-7.

The principal remote sensing satellite series now in operation is

LANDSAT (originally called ERTS). LANDSAT-2 was launched, in 1975, into a circular, polar, sun-synchronous orbit, at an approximate altitude of 900 kilometres and an inclination of 90 degrees. The satellite circles the earth once every 103 minutes, yielding fourteen passes per day. Near the equator it observes the same scene only once every eighteen days, or about twenty times a year (the repetition of observational coverage increases at higher latitudes). The main sensor systems on board are a three-channel radiometer (which covers the green, yellow and red wavelength bands in the visible region), a return beam vidicon (RBV) television-like camera, and a four-channel Multi-Sectral Scanner (MSS) (covering the visible green, yellow, red and infrared wave lengths). LANDSAT-3, launched in 1978, has had instrumentation problems and is no longer in full operation (that is, it is not transmitting, ground processing and disseminating data on a daily basis). LANDSAT-D, planned for launch in July 1982, will have to replace LANDSAT 1 through 3.

Space Platforms: Shuttle, Spacelab and Others

The Space Shuttle will probably be available as a low-cost satellite launching facility, as discussed in Appendix C. The Shuttle will also provide a unique space platform on which to test new sensor systems, and may provide the opportunity for short-duration missions to monitor ocean and coastal activity on relatively short notice, should appropriate sensor systems be built.

The Spacelab missions, on the other hand, can provide space-platform facilities similar to those of the Shuttle, but for durations of several weeks rather than several days. However, the Shuttle's facility for the quick repetition of a mission and its rapid deployment cannot be equalled under the Spacelab program.

Finally, another type of space platform that is worthy of note is the general purpose satellite "buses." These are satellites and communications vehicles, with standard mechanical electronic systems, into which remote sensors can be integrated to produce a spaceworthy craft. Significant savings in developmental costs can be realized, as the same bus can be used for a variety of satellites.

Communications Links and Relays

Many satellites transmit their information directly to ground receiving stations. Geostationary satellites can transmit continuously to ground stations that are in view. Some polar orbiters record information to be played back when they pass over ground stations. Others transmit directly to communications satellites in geostationary orbits, which in turn relay the information to ground stations.

Some satellites are equipped to receive surface-based in situ instrumentation transmissions from ocean buoys and remote land sites for relay to earth stations. In addition to collecting images, LANDSAT functions as a communications relay satellite through Data Collection Platforms (DCPs) located around the world. These platforms relay reference measurements from contact sensors at remote locations to the satellite, which in turn transmits the data to a primary, ground receiving station. Each DCP can collect information, every twelve hours, on as many as eight variables (such as temperature, current flow, ice depth and sonar data). This capability has many applications in coastal zone monitoring.

Appendix C

THE FUTURE OF REMOTE SENSING SATELLITES FOR CANADA

The new, second-generation LANDSAT-D technology will improve earth resource survey capabilities by providing better colour and spatial resolution. NASA intends to freeze the LANDSAT-D technology so that no station modification will be required for at least a decade. The applications of LANDSAT-D to oceans may be limited, however, although its uses in tidal and marshland studies show promise.

The Canadian government has initiated plans for the development of a Canadian-owned and -controlled monitoring satellite, called RADARSAT, to assist in meeting expected surveillance needs in the last decade of this century. The Department of Energy, Mines and Resources, the leading agency involved in the RADARSAT program, is engaged in the design phase of the system. This phase will see one satellite in orbit, with an additional satellite available as back-up. The satellite will be equipped with a Synthetic Aperture Radar (SAR), and other instruments are under review. The SAR sensor is of interest to Canada because of its ability to provide high resolution images (better than 30 metres) of ocean and land area, despite darkness or cloud cover. The RADARSAT orbit will be selected to provide optimum coverage frequency in the northern zone (above 60 degrees N). The RADARSAT system is expected to achieve a three-day northern coverage subcycle, giving good Canadian coverage. Daily coverage for all of Canada's Resource Ribbon may require two orbiting spacecraft. The first launch is planned for 1987.

The RADARSAT program would ensure Canada's access to

spaceborne SAR data, and would allow the development of sovereign capability in a specific technological aspect of surveillance satellites. The final decision on whether to proceed with RADARSAT is expected sometime in 1982.

Canada also has an interest in the Preparatory European Remote Sensing Satellite Program (PERSSP) of the European Space Agency (ESA). One interesting suggestion is that Canada could contribute to this international program by supplying a SAR sensor. Canada is also discussing, with Japan and the United States, the possibility of incorporating the Canadian SAR on their respective satellites.

Manned space platforms (for example, SKYLAB and SPACELAB) will play a significant role in remote sensing from space with the commencement of the Shuttle flights. It is expected that the Shuttle will lower the cost of launching remote sensing satellites significantly. It will also be capable of servicing satellites in space or bringing them back to earth.

A spin-off from the Shuttle is a proposal for a Multimission Modular Spacecraft (MMS). It consists of a central structure to which modules could be attached for power supply, data handling, communications, and orbit and altitude control. Specialized payload modules for remote sensing, weather monitoring, or other applications could then be attached as necessary.

NASA is developing the Large Format Camera (LFC) for testing on Shuttle missions. The high resolution of LFC data should make it useful in those applications where repetitive global coverage is not essential.

Of additional interest to Canada is the launch of the first French remote sensing satellite, SPOT-1, scheduled for 1983 on the European launch vehicle, the Ariane. The ESA is also planning to launch its first remote sensing satellite, ERS-1, in 1986. It will have a SAR on board, and is intended for coastal zone and ocean monitoring applications. An ocean monitoring satellite, also called ERS-1, is being planned currently by Japan.

In the interest of ensuring supplies of remote sensing data, Canada should maintain a close dialogue with all of the nations that are planning ocean and coastal zone satellite monitoring systems.

Appendix D
CANADIAN GROUPS INTERESTED OR ACTIVE IN OCEANIC REMOTE SENSING

(The listings below include name of group, location, area of expertise and/or projects and collaborators, if any; * denotes group contacted in the preparation of this report.)

Federal Government

- *Atmospheric Environment Service
  Department of the Environment
  Toronto, Ontario
  -- Data collection, analysis, processing; weather forecasting; ice research; meteorological and oceanographic research.

- *Bedford Institute of Oceanography (including Atlantic Geoscience Centre)
  Department of Fisheries and Oceans
  Dartmouth, Nova Scotia
  -- Atlantic oceanographic laboratories for chemical, physical and biological oceanic research; marine ecology; geoscience.

- *Canada Centre for Inland Waters
  Department of Energy, Mines & Resources
  Ottawa, Ontario
  -- Research and development of sensors; telemetry; data collection/processing; imagery processing, display and analysis.

- Canada Centre for Space Science
  National Research Council
  Ottawa, Ontario
  -- National space science policy and direction.

- Canadian Coast Guard
  Department of Transport
  Dartmouth, Nova Scotia & Victoria, British Columbia
  -- Surveillance and patrol of coastal zones.

- Canadian Forces Meteorological and Oceanographic Centre (METOC)
  Department of National Defence
  Ottawa, Ontario
  -- Collection and dissemination of meteorological and oceanographic products.

- Environmental Protection Service
  Department of the Environment
  Ottawa, Ontario
  -- Air-water-land pollution surveillance, protection, and control.

- Harbour Planning and Development
  Harbours Board of Canada
  Ottawa, Ontario
  -- Planning, design, and development of harbours, ports, coastal zones. Also assisted by federal Department of Public Works.

- *Institute of Ocean Sciences
  Department of Fisheries & Oceans
  Sidney, British Columbia
  -- Pacific oceanography laboratories for chemical, physical, and biological oceanic research; marine ecology; geoscience.

- Newfoundland Fisheries Laboratories
  Department of Fisheries & Oceans
  St. John's, Newfoundland
  -- Oceanic biological marine research, physical and ecological.

Provincial Governments

- Alberta Remote Sensing Centre
  Environment Ministry
  Edmonton, Alberta
  -- Remote sensing facilities.

- Inter-Provincial Territorial Advisory Sub-Committee to CCRS (IPTASC)
  Located in all provinces of Canada
  -- Co-ordinates any provincial remote sensing activity with CCRS.

- Manitoba Remote Sensing Centre
  Environment Ministry
  Winnipeg, Manitoba
  -- Remote sensing facilities.

- Nova Scotia Remote Sensing Centre
  Nova Scotia Land Survey Institute
  Lawrencetown, Nova Scotia
  -- Remote sensing facilities.

- *Ontario Centre for Remote Sensing
  Environment Ministry
  Toronto, Ontario
  -- Remote sensing facilities.

- Remote Sensing Services
  Ministry of Lands & Forests
  Ste. Foy, Quebec
  -- Remote sensing facilities.

Universities

- *Dalhousie University (Oceanographic Department)
  Halifax, Nova Scotia
  -- General oceanic research.

- *Memorial University of Newfoundland (Oceanography Department)
  St. John's, Newfoundland
  -- General oceanic research; Centre for Cold Ocean Resources Engineering Ltd.; environmental, biological, marine.

- University of British Columbia (Institute of Oceanography)
  Vancouver, British Columbia
  -- General oceanic research; Westwater Research Centre; biological, ecological, environmental and marine pollution.

- University of Victoria (various departments)
  Victoria, British Columbia
  -- General oceanic research; biological, environmental pollution.

- *York University (Centre for Research in Experimental Space Science)
  Toronto, Ontario
  -- Instrumental development, data processing, opto-electronics, spectral analysis remote sensing technology.

Commercial Firms

- Arctic Sciences
  Sidney, British Columbia
  -- Oceanic research.

- Barringer Research/Magenta Ltd.
  Rexdale, Ontario
  -- Sensor systems.

- Bercha Associates Ltd.
  Calgary, Alberta
  -- Sensor systems.

- Bristol Aerospace Ltd.
  Winnipeg, Manitoba
  -- Sensor systems.

- Bruneau Resources Limited
  St. John's, Newfoundland
  -- Oceanographic research.

- *C-Core Ltd.
  St. John's, Newfoundland
  -- Oceanographic research.

- *Dome-Petroleum Limited
  Calgary, Alberta
  -- Beaufort Sea exploration with airborne photography and radar; satellite, radar and microwave sensing; laser profiling; acoustic sensing for ice reconnaissance.

- Esso Resources Canada Ltd.
  Calgary, Alberta
  -- Davis Strait exploration.

- Gulf Canada Ltd. (Remote Sensing Group)
  Calgary, Alberta
  -- Arctic and Hibernia exploration.

- Hermes Electronics Limited
  Dartmouth, Nova Scotia
  -- Oceanographic research.

- IMP Group Ltd.
  Dartmouth, Nova Scotia

-- Remote sensing of icebergs and ice distribution.

- Interra Environmental Consultants Ltd.
  Ottawa, Ontario
  -- Sensor systems, display systems, data processing systems.

- *ITRES Research Inc.
  Calgary, Alberta
  -- Computer display systems, sensor systems.

- *Philip A. Lapp Ltd. & Huntec-Lapp Systems Ltd.
  Toronto, Ontario
  -- Scientific systems management, remote sensing technology, and space science.

- Maclaren Marex Inc.
  Dartmouth, Nova Scotia
  -- Oceanographic research.

- Maritime Technology Consultants Ltd.
  Halifax, Nova Scotia
  -- Marine technologies, ocean surveillance systems, technology assessment.

- McDonald, Dettwyler & Associates Ltd.
  Richmond, British Columbia
  -- Satellite receiving station systems, data display.

- Mobil Oil Canada Ltd.
  Calgary, Alberta
  -- Hibernia exploration.

- Moniteq Ltd.
  Concord, Ontario
  -- Sensor Systems, data analysis.

- Motorola Canada Ltd.
  Toronto, Ontario
  -- Remote sensing and instrumentation: Labrador Shelf and the arctic.

- NORDCO
  St. John's, Newfoundland
  -- Oceanography, meteorologic research.

- *Petro-Canada
  Calgary, Alberta
  -- High arctic and Labrador coast and Beaufort Sea exploration with airborne radar, satellite radar, infrared and visible imagery.

- *Ph.D. Associates Inc.
  Downsview, Ontario
  -- Scientific applications of computing data processing, remote sensing data collection, display analysis, dissemination, ice monitoring and modelling, satellite data mapping.

- Remotech Application Inc.
  St. John's, Newfoundland
  -- Shipborne remote sensing–Arctic Pilot Project.

- SED Systems Ltd.
  Saskatoon, Saskatchewan
  -- Sensor systems.

- Shell Canada Ltd.
  Calgary, Alberta
  -- Beaufort Sea exploration.

- SPAR Aerospace Ltd.
  Toronto, Ontario
  -- Sensor systems, sensor platforms, CanadArm.

- *Telespace Information Ltd.
  Toronto, Ontario
  — Satellite technology, information and communications.

Appendix E
GLOSSARY OF TERMS

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acoustic sensors: in situ sensors that either record sounds produced in the oceans (by ships, exploration activities, fish, geological, waves, etc.) or record echoes from sounds created by the sensor system.

bergy bit: piece of sea ice as large as a small house.

CZCS: (Coastal Zone Colour Scanner)–an imaging sensor operating in the visible and near-infrared wave length regions.

data: numerical information of which there are three types:

- raw data: information such as output values from sensors, given in instrumental units or converted to physical units.
- analysed data: uses raw data and yields results such as environmental parameters interpreted by human and/or computer-manipulated algorithms.
- data products: uses analysed data to prepare information for use in final products, such as maps, forecasts, charts.

data management: the collection, archiving, cataloguing, processing and preparation of user products, as well as the dissemination of products and information.

downwelling: the downward movement of water currents in the ocean.

fast ice: ice frozen or locked into a land mass; may be partially overlaying the land mass.

FLI: (Fluorescence Line Imager)—an imaging sensor designed to detect specific colours of visible wavelength light from oceanborne plant life.

GOES: oceanographic polar orbiting satellite carrying a radar altimeter.

GOES: Geostationary Orbit Environmental meteorological satellites.

growler: piece of sea ice ranging in size from that of an office desk up to that of a grand piano.

in situ: in position; in the area being observed, localized to a small area.

infrared: region of light with wavelengths longer than that of visible light (5×10^{-5} m.).

LANDSAT: experimental earth resources satellite series.

lead: open water channels in the sea ice.

microwave and radar: region of light with wavelengths much longer than that of visible light (5×10^{-3} m.).

NIMBUS: experimental meteorological satellite (radar/microwave/visible/infrared sensors).

NOAA: operational meteorological ("weather") satellite series.

oceans management: observing, monitoring, and understanding our oceans, and legislating and controlling man's activities in and uses of the ocean and its coastal zone resources.

Oceans Remote Sensing Data Operations (Oceans Operations): the routine production of information derived from routine remote sensing

observations, data collection, data analysis and interpretation; also, user information display, product development and dissemination.

Oceans Remote Sensing Data Research (Oceans Research): the collection, analysis, understanding and interpretation of remote sensing data in combination with in situ laboratory and theoretical data comparisons.

pack ice: any area of sea, river or lake ice other than land or fast ice.

polynya: any water area in pack ice or fast ice other than a lead.

push broom scanner: an imaging sensor using a specialized high-speed electronic read-out technique.

radar:
- electromagnetic energy in the centimetre wavelength region.
- active radar (SAR, SLAR, scatterometer): emits radar energy and detects target-reflected portion of emitted energy.
- passive radar: detects naturally occurring radar energy emitted from all targets; caused by the target's thermal temperature.

RADARSAR: a proposed all-Canadian satellite (now in the concept and design phase of study); intended to carry at least a SAR and one other radar instrument for oceans monitoring.

SAR: (Synthetic Aperture Radar)—a high-resolution active radar-imaging sensor capable of being carried in an airplane or on a satellite platform.

scatterometer: active radar used to detect ocean surface roughness by measuring the radar signals reflected (or scattered) by ocean waves.

sea ice: any form of ice that has resulted from the freezing of sea water.

SEASAT: an experimental oceans and weather-related satellite that carries, among other instruments, the following all-weather radars: altimeters, a scatterometer, a passive microwave radiometer, and a synthetic aperture radar.

ships of opportunity: any vessel on the ocean (travelling, anchored or stationary) from which oceans information can be obtained, measured or transmitted (e.g., a commercial or military ship en route, exploration vessels, drilling platforms).

SLAR: side-looking airborne radar.

SURSAT: extensive group of studies detailing Canadian needs for surveillance satellites.

synoptic: short-term view, often covering a broad area of activity, for the purposes of monitoring and forecasting.

tactical data: data measured within a few hours of request, or from specifically required areas.

TIROS: experimental meteorological satellite series.

upwelling: the upward movement of water currents in the oceans.

visible: region of light with wavelengths visible to the human eye (5×10^{-7} m.).

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